NEWSLETTER OF THE COOPERATIVE RESEARCH CENTRE FOR CATCHMENT HYDROLOGY

CATCHWORD

NO 117 JUNE 2003

A NOTE FROM THE DIRECTOR

Professor Rob Vertessy

Inside...

COOPERATIVE RESEARCH CENTRE FOR
CATCHMENT HYDROLOGY

THE WATER FORUM CRCS AND THE ANNUAL CRCA CONFERENCE

Each year, the Cooperative Research Centre's Association (CRCA) holds a conference to showcase the achievements of CRCs and to share experiences between different CRCs. This year, the CRCA Conference was held in Canberra under the theme 'CRCs Connecting Communities: Meeting National Research Priorities'. Almost all of the 71 CRCs funded by the Commonwealth participated in the Conference this year, with a large number of Board Chairs, Directors (or CEOs), Business Managers and Program Leaders attending. I had the opportunity to give a presentation on behalf of the five 'Water Forum CRCs', including our own CRC, the CRC for Freshwater Ecology, the CRC for Water Quality & Treatment, the CRC for Waste Management & Pollution Control, and the CRC for Coastal Zone, Estuary Waterway Management. My talk was entitled 'Meeting the needs of different communities in water debates' and attempted to show how the five Water Forum CRCs are assisting government, industry and the community to grapple with one of our nations top research priorities: the sustainable use of water.

I began the talk by highlighting the public controversy that surrounds water issues; to do so I showed a sample of the water-related headlines from the ABC News Online web site over the previous week. Next I illustrated that whilst Australia has significantly lower water availability than any other continent, we also use much more water per capita than any other continent. I pointed out that in the populous south east of Australia, water resources have been highly committed, primarily during a time of wetter-than-average conditions (1945-85). I argued that the current water shortages we are experiencing could become even more uncomfortable if we were to experience a long drying phase such our forebears experienced in 1900-45 and our contemporaries are now experiencing in south western Australia.

At the end of my introduction I summarised the key features of water in Australia. There is significant public interest in water, accompanied by significant public investment, including over $70 billion invested in water infrastructure. Water management is problematic because of the complex institutional arrangements; the Commonwealth, States and Territories, Murray-Darling Basin Commission, Local Governments, various Regional Authorities, and private companies are also involved. Water is also often a divisive issue. Whenever a resource is limited and/or its misuse results in environmental degradation, one can expect polarised attitudes regarding how best to manage it. Currently, for instance, there is a reasonably strong 'city versus bush' argument prevailing over how to best manage flows in the Murray River. Water issues are bedevilled by complexity and uncertainty. Our scientific knowledge is far from complete, and it remains a challenge for us to give authoritative advice across a large continent characterised by significant physico-climatic and biological diversity. Two decades worth of downsizing and associated de-skilling in water management agencies make it more difficult than ever for government to keep on top of the issues. And finally, although water is a mainstream media issue, the level of 'water literacy' is generally low in the Australian community. Any cursory reading of a national newspaper will reveal that most Australians are far better informed about the economy than water sustainability; I regularly despair at the calibre of reporting on water issues in the media.

So you ask, how are the five Water Forum CRCs making you all sleep better at night? Well first, by investing in five water-related CRCs the Commonwealth government and the various organisations party to these CRCs are acknowledging the public's rising expectations for science-based decision making in water management. The Water Forum CRCs are about bringing state-of-the-art knowledge, tools and technology 'to market' with unprecedented speed and completeness. A big part of our collective success, and in essence the genius of the CRC Program at large, is the glue that each Water Forum CRC provides for an industry that is both disparate and thin. Through our various partnerships we are pooling knowledge, focussing on industry priorities, sharing resources and reducing duplication and competition. We work across the institutional spectrum as 'honest brokers' and are trusted sources of information and advice. The commitment we are each making to Communication & Adoption, and Education & Training, is making for a much more highly skilled water industry. Together, we have produced over 250 PhD graduates and many of them now occupy important roles in the Australian water industry and R&D sector. Several of the water Forum CRCs are also reaching out to the community in innovative ways, raising the standard of public debate and reducing conflict amongst stakeholders.

CRC PROJECT PORTFOLIO (2003-2005)

The CRC has published a 'Project Portfolio' which gives readers an overview of the CRC, its mission and short summaries of all new CRC projects (2003-2005).

Copies can be obtained from the Centre Office by contacting Virginia Verrelli on 03 9905 2704.

The document can also be downloaded as an Adobe Acrobat .pdf file from our website at www.catchment.crc.org.au/news

For further information please contact David Perry on 03 9905 9600.

Each of the five Water Forum CRCs works differently, being a product of the organisations and individuals based within them. This diversity has been helpful, as we have learnt from one another's successes and failures.

In preparing my talk for the CRCA Conference and through various Water Forum meetings, I've learnt a lot about what our fellow water CRCs are doing and how our own CRC can be more effective. Collectively, the Water Forum is a powerhouse of talent and idealism, making a significant impact on the Australian water industry, and a vital contribution to the Australian community. Our own CRC is devoted to playing a strong role in this bigger initiative.

Rob Vertessy
Tel: (02) 6246 5790
Email: rob.vertessy@csiro.au

PROGRAM 1

PREDICTING CATCHMENT BEHAVIOUR

Program Leader
GEOFF PODGER

Report by DD Kandel, Andrew Western and Rodger Grayson

Temporal scaling in surface runoff and erosion modelling

Introduction

Modelling is a key tool in hydrological analysis and a key mechanism for delivery of CRC for Catchment Hydrology research. Models operating at certain scales attempt to mimic hydrological processes that occur at other scales. For example, processes such as infiltration excess, overland flow, soil erosion, sediment and pollutant transport are dominated by instantaneous rainfall intensity, yet we often wish to model them with daily time-steps. Data collection and measurements in the field are also made at certain spatial and temporal scales, not necessarily matching that of the dominant processes. Data provides the basic empirical information on which modelling is based and its availability often dictates modelling scales. For example, daily rainfall data may constrain modelling at shorter-time-scales. In such cases, process descriptions in the model are often not modified, but 'effective parameter values' are used to account for the effect of temporal lumping. A similar approach is commonly taken spatially. Such scale-mismatches have important consequences because, for example, time-averaging causes a considerable loss of detail in the temporal distribution of rainfall and runoff, resulting in significant attenuation of the peak rates that are critical to the processes involved. That is why daily models often perform poorly in simulating short-time-scale processes (eg. Kandel *et al.*, in press; Socolofsky *et al.*, 2001).

Appropriate methods of scaling may effectively address this problem. DD Kandels' PhD research has addressed temporal scaling of rainfall in surface runoff and erosion modelling. Scaling of rainfall statistically has significant scope in utilising daily data more appropriately. It allows modelling of processes at various time scales since it tends to preserve prediction quality as time scales become coarser. The statistical description of sub-daily characteristics of rainfall enables the modellers constrained by daily data, to overcome the critical effects of time-averaging and attenuation.

In this study we develop a practical framework to represent key sub-daily characteristics of fluxes. This development is an alternative way of simulating surface runoff and erosion fluxes by scaling rainfall that captures the fine time scale processes while retaining the daily modelling time steps, as supported by commonly available daily data.

Temporal scaling approaches

We began by studying three approaches to temporal scaling: (1) temporally lumped effective parameters ('daily model'), (2) effective rates ('daily wet-model'), and (3) synthetic time series obtained by disaggregating daily rainfall ('disaggregation model').

The first approach involves some lumping and averaging (and violation) of natural conditions by aggregation and the resulting parameters are considered to be effective for the scale in question. This approach often results in unstable or unreliable and physically implausible parameters. It also leads to a reduction in model performance since the effects of time averaging cannot be adequately overcome, particularly for simulation of infiltration excess runoff and erosion production mechanisms.

The second approach concerns the wet part of the day (storm periods) and has been shown to be an improvement over the first approach (Kandel *et al.*, in press), however, at the cost of substantially increased in number of parameters.

The third approach is based on running models at finer time steps, using stochastic generation of sub-daily rainfall data. It has been receiving the increasing attention of modellers since the use of disaggregation approaches enables process simulation at various time scales and improves the models' performance. Various studies have shown that this approach is comparable to sub-hourly model simulations using pluviograph data (eg. Kandel *et al.*, in press; Socolofsky *et al.*, 2001). While this approach is potentially applicable to many models for various purposes, it is computationally expensive. An alternative to this is a distribution function approach that is conceptually, as well as practically, more appealing as a general scaling tool.

Cumulative Distribution Function (CDF) as a temporal scaling tool

Distribution functions have been used in hydrological studies to characterise the spatial variation of random variables (eg. soil moisture) across the catchment (eg. Hawkins and Cundy, 1987; Moore and Clarke, 1981; Sivapalan and Woods, 1995; Wooldridge *et al.*, 2002; Wood *et al.*, 1992) and Beven (1995). This literature suggests their use as a more general scaling tool. Motivated by their potential application for modelling the temporal distribution of surface runoff and erosion fluxes, this study uses CDFs as a temporal scaling tool. The distribution information is used directly rather than disaggregating daily rainfalls into synthetic time series for fine-time scale computations. This is where, in terms of temporal scaling, a distribution function approach differs from disaggregation. It is meant to capture shorter-time-scale (minutes) processes using daily rainfall values as input and retaining the daily time-step computation.

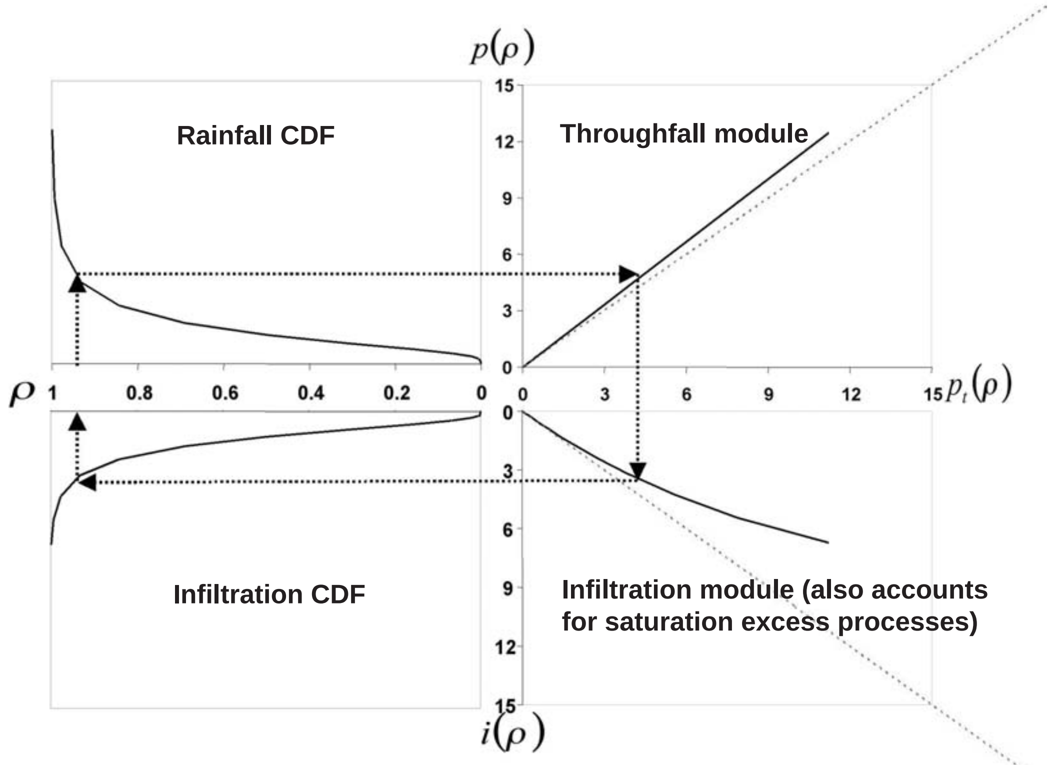


Figure 1.1. Translation of rainfall CDF to throughfall CDF (not shown) and infiltration CDF. The runoff CDF is calculated as the difference between throughfall and infiltration CDFs. Both the runoff and throughfall CDFs are input to calculate the erosion CDF.

FOREST MANAGEMENT WORKSHOP AND FIELD DAY - CANBERRA

RE-SCHEDULED FOR 9-11 DECEMBER 2003

The recently promoted Forest Management workshop arranged through a partnership between the University of New South Wales, NSW State Forests, the Forest Science Centre and the CRC for Catchment Hydrology has been re-scheduled for the 9-11 December 2003.

Four major themes will be addressed during the first two days of this workshop:

- Forest Hydrology
- Sediment Delivery and Water Quality
- Fire Management
- Sustainable Forestry

The third day will be a field trip for participants to visit the burnt forest west of Canberra and NSW State Forest plantations near Tumut.

For further information regarding the workshop and how to register as a presenter or participant please contact David Perry on 03 9905 9600 or email david.perry@eng.monash.edu.au

OTHER OUTLETS FOR CRC PUBLICATIONS

In addition to the Centre Office, all CRC publications are available through the Australian Water Association (AWA) Bookshop in Sydney and the Department of Sustainability and Environment (DSE) Resource Centre in Melbourne. AWA and DSE also stock a wide range of other environmental publications.

AWA Bookshop (virtual)
contact Diane Wiesner
Bookshop Manager
tel: 02 9413 1288
fax: 02 9413 1047
email: bookshop@awa.asn.au
web: www.awa.asn.au/bookshop/

DSE Resource Centre
8 Nicholson Street (cnr Victoria Parade)
PO Box 500
East Melbourne
Victoria 3002 Australia
publication.sales@nre.vic.gov.au
Phone: 03 9637 8325
Fax: 03 9637 8150
www.nre.vic.gov.au
Open: 8.30-5.30, Monday to Friday

In this CDF based scaling approach, the sub-daily rainfall dynamics within a rainy day are represented by a cumulative distribution function. By translating this rainfall CDF into process descriptions, rainfall-runoff-erosion algorithms can be modified to get the runoff and erosion CDFs directly (hereafter referred to as CDF model). This CDF transformation process is shown in Figure 1.1, in which a rainfall CDF is modified by the interception and infiltration processes to derive a CDF for infiltration. The difference between the CDFs of throughfall, and infiltration and saturation excess processes gives runoff CDF, which is applied along with throughfall CDF to an erosion algorithm to determine the erosion CDF. This allows simulation of CDFs of runoff and erosion with a temporal support (averaging period) normally associated with sub-hourly time scale processes, while retaining the daily model timesteps. That is, the effects of temporal variation within the day are retained without the temporal pattern being explicitly simulated. Therefore, the essence of this method is the translation of the rainfall CDFs into the CDFs of surface runoff and erosion fluxes rather than computing individual values for each intensity input. The resulting CDFs are integrated over the wet period to obtain the respective daily loads.

Model application at plot scale

Five different models were tested in the plot scale application - four models representing each of the temporal scaling approaches mentioned above and one sub-hourly model used as a reference. Only the daily, CDF and sub-hourly model were considered - these represented (i) typical practice, (ii) the best of the scaling approaches studied, and (iii) the reference case. Forty-two-plot-years of daily runoff and erosion data from field studies in Australia (18-plot-years between 1981 - 1986, Gunnedah, NSW) and Nepal (24-plot-years between 1997 - 2000, Jhikhu Khola watershed) representing different environments were used. Pluviograph data at 6-minute resolution in Australia and 2-minute resolution in Nepal were used to provide a reference. A six-parameter rainfall-runoff and one-parameter erosion model was constructed and used for testing various models. Split-calibration and validation procedures were used in testing models. The performance, as measured by Nash's coefficient of efficiency (COE), of three models (sub-hourly, daily and CDF) are presented (Table 1.1) and briefly discussed below.

Summary of results and discussions

The results given in Table 1.1 are a subset of those in Kandel *et al.* (in press) and show that model performance degrades, considerably in some cases, when time scale shifts from sub-hourly to daily - in both calibration and validation simulations, and for both runoff and erosion prediction. The daily parameters, particularly those related to soil infiltration capacity and erodibility, are different by an order of magnitude from sub-hourly model parameters, and also look unrealistic. This is because, when the modelling time scale is much coarser than the process time scale, the parameter values tend to loose their physical significance. So we cannot expect to obtain a plausible and physically significant set of parameters by calibrating a model at the daily time-step.

When the results of various temporal scaling approaches are compared, the CDF model is found more realistic and better performing. It is superior to the daily model and compares well with the sub-hourly model in terms of accuracy and reliability. Its parameter values, like those of the sub-hourly model, are more stable. The CDF model values also seem more plausible and physically interpretable than those of the daily model.

*Table 1.1 Nash's coefficient of efficiency (COE) of various models.**

	Surface runoff		Soil erosion	
Models	**Calibration**	**Validation**	**Calibration**	**Validation**
Australia				
6-minute model	0.91	0.76	0.89	0.67
Daily model	0.81	0.76	0.62	0.54
CDF model	0.89	0.78	0.70	0.64
Nepal				
2-minute model	0.92	0.91	0.80	0.51
Daily model	0.76	0.71	0.37	-0.07
CDF model	0.91	0.89	0.70	0.51

* *The statistics represent a composite series of all plots put together (i.e. n = 3 plots x (6 x 365.25 days) = 6573 in Australia and 6 x (4 x 365.25) = 8766 in Nepal).*

As indicated by the COE statistics in Table 1.1, the CDF model also seems more stable in cross-validation simulation than other models and it performs as well as the sub-hourly model in validation. Additional results in Kandel *et al.* (in press and in preparation) illustrate the advantages of the CDF based scaling approach. The stability of the model parameters augers well for the transferability of the model both spatially (to other areas) and temporally (to other periods). Further, the CDF approach is less likely to be constrained by data limitations than an equivalent sub-hourly model, wherein a very fine scale continuous measure in the order of a few minutes is required for modelling soil erosion. It offers a realistic attempt in practically quantifying sub-daily responses using only daily information. This is a positive step towards reconciling the apparent mismatch between the fine time scale processes and temporally lumped coarse-scale response.

Conclusions

The CDF based temporal scaling shows promise but for large-scale application, it needs to be expanded spatially, particularly addressing the spatio-temporal representation of rainfall and the likely routing effects on the CDF translation through the processes.

In summary, the benefits of 'good' temporal scaling as a reflection of the CDF approach are:

- Improved model performance.
- Realistic simulation of processes and more physically plausible parameter values.
- Retention of the daily time-step, so computationally advantageous.
- Modelling at a scale at which key information and data are available
- Robust and more stable in cross-validation.
- Potentially applicable at catchment scale, though needs further research.

For more information on this work, please contact DD Kandel.

References

Beven, K., 1995. Linking Parameters Across Scales - Subgrid Parameterizations and Scale Dependent Hydrological Models. Hydrological Processes, 9(5-6): 507-525.

Hawkins, R. and Cundy, T., 1987. Steady-state analysis of infiltration and overland flow for spatially varied hillslopes. Water Resources Bulletin, 23(2): 251-256.

Kandel, D., Western, A., Grayson, R. and Turral, H., in press. Process parameterisation and temporal scaling in surface runoff and erosion modelling. Hydrological Processes.

Moore, R.J. and Clarke, R.T., 1981. A Distribution Function-Approach to Rainfall Runoff Modeling. Water Resources Research, 17(5): 1367-1382.

Sivapalan, M., and Woods, R.A., 1995. Evaluation of the effects of general circulation model's subgrid variability and patchiness of rainfall and soil moisture on land surface water balance fluxes. In Kalma, J.D., and Sivapalan, M. (Eds.), Scale Issues in Hydrological Modelling. John Wiley, 453-473.

Socolofsky, S., Adams, E., and Entekhabi, D., 2001. Disaggregation of daily rainfall for continuous watershed modelling. Journal of Hydrologic Engineering, 6 (4): 300-309.

Wood, E.F., Lettenmaier, D.F. and Zartarian, V.G., 1992. A land-surface hydrology parameterization with sub-grid variability for general circulation models. Journal of Geophysical Research, 97 (D3): 2717-2728.

Wooldridge, S.A., Kalma, J.D., Franks, S.W. and Kuczera, G., 2002. Model identification by space-time disaggregation: a case study from eastern Australia. Hydrological Processes, 16(2): 459-477.

DD Kandel
Tel: (03) 8344 7238
Email: d.kandel@civag.unimelb.edu.au

Andrew Western
Tel: (03) 8344 7305
Email: a.western@unimelb.edu.au

Rodger Grayson
Tel: (03) 8344 6623
Email: rbg@unimelb.edu.au

DOWNLOAD CRC REPORTS

All of the CRC's reports since 1999 can be downloaded from our website at www.catchment.crc.org.au/publications

You can use our search engine to find the exact report you are seeking or to list all of the reports available.

PROGRAM 2

LAND-USE IMPACTS ON RIVERS

Program Leader
PETER HAIRSINE

Report by Heather Hunter

Nitrogen & carbon dynamics in riparian buffer zones

This report provides an overview of research carried out in Project 2.5: 'Nitrogen and carbon dynamics in riparian buffer zones' (now nearing completion) and outlines future research proposed in Project 2.22: 'Modelling and managing nitrogen in riparian zones to improve water quality'. Further information on Project 2.5 can be found in our previous *Catchword* reports, for May and December 2000, August and December 2001, and June 2002. The research is jointly supported by the CRCs for Catchment Hydrology and Coastal Zone, Estuary and Waterway Management.

Background

Riparian buffer zones, particularly those on low order streams, offer the potential for reducing nitrogen entry to waterways, from both surface runoff and shallow groundwater flows. While much of the nitrogen entering streams is attached to sediment in runoff, a significant proportion is often transported in dissolved form as nitrate. Fluxes of nitrate through the riparian zone are intrinsically linked to water movement (both over and through the soil) and are also strongly influenced by biological processes occurring in that zone. The process of denitrification (microbial conversion of nitrate to nitrogen gas) is particularly important because it effectively removes nitrogen from the riparian zone to the atmosphere.

Riparian zone denitrification can have an important impact on downstream water quality when significant amounts of nitrate-enriched groundwater are transported through carbon-rich riparian soils under low oxygen conditions and at flow rates that allow enough time for denitrification process to occur. Research in the northern hemisphere and New Zealand has shown these subsurface processes to be important in the overall transport of nitrogen in catchments, with riparian zones found to reduce groundwater nitrate levels by up to 90% or more.

In Project 2.5 we have sought to investigate the importance of these processes in an Australian context and assess their implications for water quality management and the management of riparian lands.

Study site

Research in Project 2.5 has been carried out in the Coochin Creek catchment in South-east Queensland, in the well-vegetated riparian zones of a perennial stream (Coochin Creek) and a small ephemeral tributary.

Research approach

The focus has been on experimental research, which has included continuous monitoring of groundwater levels in a network of wells and piezometers installed at the two sites, and periodic monitoring of groundwater and surface water chemistry. Surface water flows and chemistry have also been monitored in the ephemeral stream. Soil cores taken from within the riparian zones and from a nearby pineapple field have provided information on particle size distribution, hydraulic conductivity and organic carbon levels in the soil profile.

We have also conducted detailed field investigations using two different approaches with inert tracers (chloride and bromide):

- an injection/capture well network; and
- a "push-pull" mesocosm technique.

From these we have gained insights into groundwater flow rate and direction, and nitrate removal.

These field investigations have been backed by detailed laboratory studies of the denitrification potential of riparian zone soils and aquifer sediments, using an 'acetylene block' incubation technique. This research has provided detailed information on denitrification processes under controlled conditions, including an assessment of the influence of organic carbon levels and time on rates of denitrification.

We have used present results from these field and laboratory studies to:

- Refine our conceptual models of nitrate transport and denitrification in riparian zones;
- Develop and parameterise prototype models of denitrification kinetics, and of interactions between groundwater and biogeochemical processes in the riparian zone of the ephemeral stream.

Some key results - ephemeral stream

- Two groundwater systems occur at the ephemeral stream site; a permanent regional water table that is connected to the surrounding land area, and a shallower transient perched water table (about 1.2 m deep) that is restricted to the floodplain of the creek.

- In the ephemeral system, groundwater - surface water interactions include a component of 'axial flow', whereby surface runoff moves from the stream into the perched water table of the riparian zone and then back to the stream further down-gradient. Initial estimates suggest that around 1% of surface runoff is diverted by this process per 100 m^2 of riparian zone. Whilst this is a small proportion of stream flow per unit area, the cumulative effects along much greater lengths of stream channel may be quite important in terms of the potential this offers for riparian zone removal of nitrogen by denitrification.
- Flow rates measured in the perched water of 5-7 cm/day provide sufficient residence time for denitrification processes to occur.
- carbon levels in the soil profile, coupled with information about maximum and minimum water table elevations, suggest a relatively low potential for denitrification of groundwater nitrate in the pineapple field, but a much higher potential in the riparian zone floodplain of the ephemeral stream. This is consistent with our hypothesis that riparian lands offer a high potential for denitrification, compared with surrounding agricultural fields.
- Under controlled laboratory conditions:
  - Denitrification rates in riparian zone soils peaked approximately 2-3 days after soils were flooded.
  - Where no carbon was added, peak denitrification rates were around 6 mg nitrate-N/g dry soil/day for shallow soils (top 30 cm of the soil profile) and 3 mg nitrate-N/g dry soil/day for deeper soils.
  - Addition of labile carbon (acetate) generally resulted in much higher rates of denitrification (15-17 mg nitrate-N/g dry soil/day).
- Field studies using tracers indicate nitrate removal of up to 40% over a five-day period.
- A simple 'bucket' model has been developed to estimate the potential for denitrification to remove nitrate from groundwater in the perched aquifer system. Based on our field and laboratory data, the model accounts for a variable detention time and a denitrification rate that varies down the soil profile and with time.

Future research

Monitoring and experimentation will continue in Project 2.22, particularly to provide further insights into groundwater - surface water interactions and riparian zone processes in the larger perennial stream system.

In Project 2.22 we propose to build on and extend our current research to:

- Develop a model to predict denitrification in riparian zones for incorporation into the CRC Toolkit's catchment water quality model/s;
- Develop a spatial analysis technique for identifying at a catchment scale, riparian zones that are intercepted by shallow groundwater flows and those at risk of high nitrogen loadings.
- Assess the potential for riparian zone management to moderate nitrogen fluxes in catchments.
- Assess the influence of management practices on the denitrification potential of riparian zones; and provide guidelines for management of riparian lands that take account of these processes and practices.

Involvement with the local community

There is widespread interest in riparian zone restoration as a practical approach to addressing water quality issues in catchments. In South-east Queensland our research has been keenly observed by community groups, landholders and industry, and through this we have had opportunities to raise their awareness of riparian zone, water quality and nutrient management issues. We anticipate that this interest will continue and that information and modelling tools produced by Project 2.22 can be used to assist community groups in their planning activities, enabling them to set priorities and evaluate potential benefits from riparian restoration works.

Acknowledgments

The research outlined in this report represents collective contributions from members of the project team: David Rassam, Christy Fellows, Rob DeHayr, Philip Bloesch, Nerida Beard, Bernie Powell, Keith Preston, Stuart Bunn, Heather Hunter (Project Leader); plus valued input from our CRC vacation students, Josie Carwardine, Andrew Mullens and Ruth Duncan. We thank our CRC project review panel, Russell Mein, Barry Hart, Sébastien Lamontagne, Peter Hairsine and Rob Vertessy for their advice and guidance during the course of this research.

Heather Hunter
Tel: (07) 3896 9637
Email: heather.hunter@nrm.qld.gov.au

WEATHER RADAR CONFERENCE

Sixth International Symposium on Hydrological Applications of Weather Radar

2-4 February 2004
Melbourne, Australia

The major theme of this conference is 'The successful implementation of radar technology for hydrological and quantitative rainfall applications'.

For more information on the symposium, please visit www.bom.gov.au/announcements/conferences/hawr2004 or email hawr2004@bom.gov.au

The conference is supported by the Commonwealth Bureau of Meteorology, the CRC for Catchment Hydrology and the Australia Meteorological and Oceanographical Society

NATIONAL CONFERENCE ON INTEGRATED CATCHMENT MANAGEMENT (ICaM - 2003)

26-27 November 2003 Parramatta, NSW

ICaM - 2003 aims to bring together practising scientists, engineers, policy makers, community educators and academics in the field of environment and catchment management.

Case studies from around Australia are especially encouraged, providing delegates with opportunity to share their problems and solutions with the wider water resource community.

For further information about contributing papers or attending please email your query to icam2003@awa.asn.au

Figure 2.1: Monitoring of stream flow in the ephemeral creek

Figure 2.2: Christy Fellows and Andrew Mullens conducting a tracer study using the 'push-pull' technique to measure denitrification in the field.

Both photos taken by Rob DeHayr

PROGRAM 3

SUSTAINABLE WATER ALLOCATION

Program Leader
JOHN TISDELL

Program Leader: John Tisdell

Policy recommendations arising from research into maturing water markets

The research conducted in Project 3.2: 'Enhancement of the water market reform process: A socio-economic analysis of guidelines and procedures for trading in mature water markets', and Associated/Additional Project 3.4 (GRU25) resulted in a number of catchment and national policy recommendations. The recommendations stemmed from an extensive review of water management literature, surveys of irrigator and community attitudes to water reform across three of our focus catchments, and a series of laboratory and field experiments.

The key recommendations included:

A. Establish a further series of tranche payments, paid to State authorities demonstrating that their water market structures have led to increased water use efficiency and account for the externalities arising from trade

Review of the literature on water management in Australia shows few incentives for State water authorities to demonstrate effective water market results. Incentive schemes focus on establishing the legal structure for water markets, but provide limited measures or incentives to operationalise or measure water market performance. Data demonstrating water moving to higher value cropping is only part of the picture.

B. Develop a series of strategies to address stakeholder apprehension towards water markets

The survey results suggest that apprehension to trading water is a significant barrier to trade and remains largely unaddressed. Survey results suggest that the opportunity cost of growing a crop is not realised in the market. A significant number of farmers responding to the survey view water as an integral part of their farm and not for sale, or were philosophically opposed to trade. Farmers surveyed are largely selling surplus water and are not willing to change farming practices to realise the full returns from water trading. They saw selling only surplus water as their strategy for the foreseeable future. This is a cultural and institutional problem that needs to be readdressed

C. Establish information forums to assist farmers in understanding how markets operate in respect to market price determination and how to develop trader strategies

Survey and experimental results suggest that farmers have limited knowledge of how markets operate and are keen to acquire more information. A large number of farmers attending the Mwater demonstrations did not understand how the market price is determined and were very keen to have this explained. It was evident that once they understood how the market operates they were able to better manage their allocation and trade decisions.

D. Give water authorities powers to restrict trades which results in social and environmental externalities

The survey of irrigators suggested that water authorities should be able to intervene in trades that may impact on other entitlements; the viability of local towns and community; and environmental flow objectives, are not just or equitable. Accounting for these externalities is important to achieve an economic optimal result from trade. Despite realising the social costs of extraction, participants in the experiments followed self-interest strategies and suffered the tragedy of the commons.

E. Revise policy expectations as a result of sub-optimal outcomes

Experimental results suggests that the rate of market convergence is likely to be slow as a result of the market apprehension, uncertainty of rainfall and limited market information. Most field markets are unlikely to achieve optimal outcomes within the first 8-10 years.

F. Increase the availability of market information

A major limitation achieving market efficiency is market information. Beyond the formal exchanges of Victoria, farmers have limited market information. Survey and experimental results (reflected in open, as opposed to closed, call auction structures) suggest that a lack of trade information is a major inhibitor to achieving market efficient outcomes. Even the release of market prices has been shown to significantly improve market efficiency.

G. Establish more formal market exchanges

While some state and regional water authorities have set in place the legal requirements for trade, in many cases they have failed to establish any formal market structures. In such circumstances farmers establish bilateral trade agreements often with little or no market knowledge. Experimentally such

HYDROLOGIC IMPACTS OF BUSHFIRES WEBSITE

In response to many requests for information about the hydrologic impacts of the recent bushfires, the CRC has established a website to deliver relevant information to catchment and water supply managers.

The site is a modest resource at this point and will evolve as more contributions are made. The site initially features a FAQ section designed for land and water managers, an overview of the hydrologic impacts of fire, a news page for information about related activities and reference lists that will be of particular interest.

The site can be found at www.catchment.crc.org.au/bushfires

The CRC welcomes contributions from all individuals and organisations to the site to expand its value to land and water managers.

If you can contribute to this site please contact david.perry@eng.monash.edu.au

NON-STRUCTURAL STORMWATER QUALITY BEST MANAGEMENT PRACTICES - NEW REPORTS

Non-structural Stormwater Quality Best Management Practices - An Overview of their Use, Value, Cost and Evaluation

By
André Taylor
Tony Wong

Technical Report 02/11

This report presents an overview of a CRC project co-funded by EPA Victoria that investigated the use, value, life-cycle costs and evaluation of non-structural best management practices (BMPs) for improved urban stormwater quality and waterway health.

The report costs $27.50 and can be ordered through the Centre Office by contacting Virginia Verrelli on 03 9905 2704 or email crcch@eng.monash.edu.au

bilateral trade environments have been shown to perform very poorly and rarely result in competitive market prices. Simply establishing markets without a formal exchange will not achieve market efficient outcomes. Markets require some form of structure in which market information, such as buy and sell bids, is transparent. Formal, centralised exchanges such as watermove should be promoted.

H. Actively involve irrigator and irrigator groups in managing aggregate extraction in order to better meet environmental flow objectives

Survey and experimental results suggest that including the establishment of forums for irrigators to self-manage aggregate extraction levels, as part of a suite of policy instruments to manage flow regimes, may be effective. To be effective, such forums require environmental flow information and necessary aggregate information. Providing a bulk entitlement to the environment may be necessary but not sufficient to effectively manage the tradeoffs between extractive and environmental water use. Trade in water entitlements limits the effectiveness of joint coordination of this nature.

I. Recognition that water markets are still in their infancy in Australia and highly vulnerable to internal and external shocks

Water markets are still highly volatile and thin. While volatility is part and parcel of resource markets with derived demand to some degree dependent on the weather, it is exacerbated by the lack of market knowledge.

J. Need for precautionary principle

Continued research into the likely consequences of large scale intra and interstate trade on water supply security and physical systems, regional economies, social structures and riverine ecosystems is vital. Until we have a greater understanding of the consequences of establishing water markets at a national scale, the research suggests that caution should be the order of the day.

The future

These projects have developed options for water policy based on an extensive review of the literature and an extensive survey of irrigator and community opinion, and developed a model for experimentally evaluating alternative resource management policy options. The recommendations provide input for policy makers to improve water markets in Australia and a platform for further research.

The next round of projects will explore policy options concerning permanent water markets, the unbundling of water property rights, auctions structures for non-point pollution permits, ecosystem services and the nature and role of environmental and resource managers in a market environment through a series of experimental simulations.

John Tisdell
Tel: (07) 3875 5291
Email: j.tisdell@mailbox.gu.edu.au

PROGRAM 4

URBAN STORMWATER QUALITY

Program Leader
TIM FLETCHER

Report by David Newton

Porous pavement as a treatment device for impervious area runoff

Article Summary
Experimental results are presented for suspended solids removal by porous pavement treating impervious area runoff. Even at high flows, representing a large contributing impervious area, removal rates of greater than 90% were observed.

Background
The potential of porous pavement to meet the key stormwater management objectives of peak discharge control, pollutant removal and runoff volume reduction has been recognised for several decades. However, concerns over maintenance and the structural inferiority of porous pavements have led to interest in pavement systems that utilise both pervious and impervious pavements (Rommel *et al.* 2001). In such systems the porous pavement acts as a treatment device for impervious area runoff. The treatment performance of the porous pavement is a function of runoff quality, the contributing catchment area, site hydrology and internal hydraulic conditions within the pavement. Whilst a large number of such systems are currently in successful operation around the world (Raimbault 1997), few controlled studies have been undertaken to determine the relative contribution of different treatment processes and the sensitivity of treatment performance to the various design parameters.

A current research program at Griffith University is investigating the hydrologic and water quality performance of combined pervious/impervious pavement systems. The program is based on separate experiments to assess potential runoff volume reduction and pollutant removal. This article summarises preliminary results from the pollutant removal experiments.

Experimental Setup
Suspended solids removal by porous pavement is being investigated by experiments on a section of porous pavement constructed within a purpose-built flume 7.2 m long x 0.5 m deep x 0.3 m wide (see Figure 4.1). Inflows to the pavement are seeded with pollutant concentrations representative of recorded values for road runoff and delivered as surface flow, simulating runoff from an adjacent impervious area. Hydraulic conditions within the pavement are controlled by a valve at the downstream end of the flume. Sample ports (see Figure 4.1 inset) are fitted throughout the length and depth of the pavement to enable internal water quality variations to be examined. The base of the pavement is sealed, simulating a porous pavement constructed on an impervious membrane.

The experimental pavement utilises lattice-type surface blocks on a graded gravel sub-base. The use of a bedding layer of compacted fine gravel eliminates the need for a geotextile between the sub-base and bedding layers. Numerous studies (Pratt 1990; Niemczynowicz 1990, Hogland *et al.* 1987) have identified clogging of the geotextile layer as an important mechanism for particulate removal. This is also the primary mechanism for the reduction of infiltration capacity which is the principal operational concern for all forms of porous pavement. Hence, a key objective of the experimental program is to determine the effectiveness of a system relying on coarse media filtration and sedimentation for particulate removal, rather than filtration through the geotextile layer.

Experimental Results and Discussion
The constructed pavement was found to be capable of infiltrating up to 7.5 L/s per m width before overflow commenced. The observed infiltration capacity exceeded 90 m/hr. However, as the flow rate onto the pavement increases, saturation of the sub-base begins to control the infiltration rate.

Pollutant removal was investigated for steady-flow conditions at 1.2, 3.0, 4.7 and 5.3 L/s per m width. Based on a rainfall intensity of 100 mm/hr these flow rates correspond to ratios of impervious area to pervious area of 5, 12, 22 and 25 respectively. At 1.2 L/s per m width, the entire flow entered the pavement almost immediately with

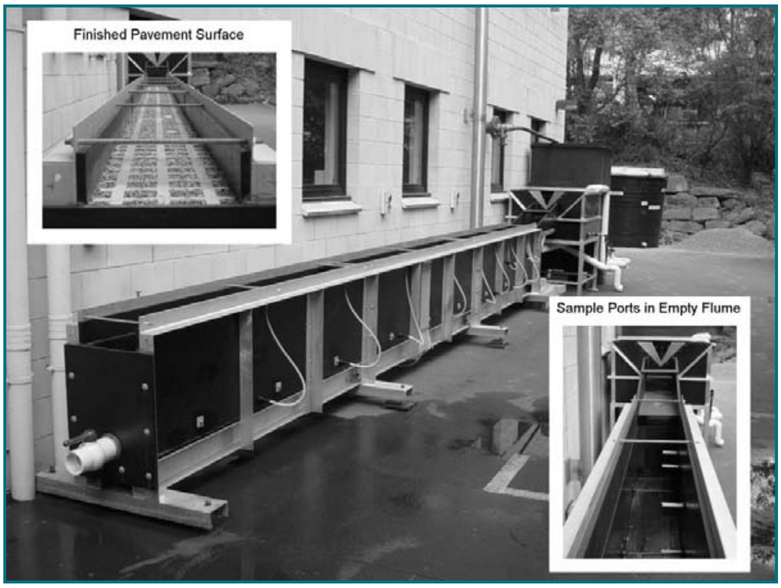


Figure 4.1 Experimental Porous Pavement Flume

NON-STRUCTURAL STORMWATER QUALITY BEST MANAGEMENT PRACTICES - NEW REPORTS

Non-structural Stormwater Quality Best Management Practices - A Survey Investigating their Use and Value

By
André Taylor
Tony Wong

Technical Report 02/12

This CRC publication is one of four reports in a series of reports on Non-structural Stormwater Quality Best Management Practices. This report documents and analyses the findings of a detailed survey of 36 Urban Stormwater Managers from Australia, New Zealand and the United States.

A printed and bound copy of the report costs $27.50 and can be ordered through the Centre Office by contacting Virginia Verrelli on 03 9905 2704 or email crcch@eng.monash.edu.au

NON-STRUCTURAL STORMWATER QUALITY BEST MANAGEMENT PRACTICES - NEW REPORTS

Non-structural Stormwater Quality Best Management Practices - A Literature Review of their Value and Life-cycle Costs

By
André Taylor
Tony Wong

Technical Report 02/13

This CRC publication is one of four reports in a series of reports on Non-structural Stormwater Quality Best Management Practices. This report presents the findings of a literature review on the value and life-cycle costs of non-structural BMPs to improve urban stormwater quality.

A printed and bound copy of the report costs $27.50 and can be ordered through the Centre Office by contacting Virginia Verrelli on 03 9905 2704 or email crcch@eng.monash.edu.au

a wetting front extending less than 100 mm onto the pavement. At the highest flow rate (5.3 L/s/m) the wetting front extended some 3.3 m onto the pavement. The inflow was seeded with a concentrated solution of silica powder with a particle size distribution similar to that observed for road runoff in south-east Queensland (Drapper 2000). The target inflow suspended solids concentration was 200 mg/L.

Figure 4.2 shows the variation in suspended solids concentration through the pavement sub-base for the four flow rates. Results are presented as a percentage of the influent concentration. Despite the absence of a geotextile layer, Figure 4.2 indicates that the constructed pavement can provide effective removal of particulate material, even under high hydraulic loadings. The primary mechanism for particle removal appears to be filtration in the surface layer. For the flow rates shown in Figure 4.2, a minimum of 84% of the pollutant inflow is removed by passing through the surface layer into the pavement sub-base. Further treatment in the pavement sub-base is a second-order effect, removing an additional 7% to 10% of the inflow concentration.

Suspended solids removal for all flow rates is between 91% and 94% and is not correlated with discharge. A possible explanation for this finding is the changing hydraulic behaviour as discharge increases. At high flow rates, the results of Lithium tracer studies indicate a bi-modal response, with a short-circuiting path across the saturated pavement surface and a "long-circuiting" response from water within the saturated pavement zone where the hydraulic gradient is reduced by the occurrence of surface flow. Note that hysteretic effects associated with unsteady flow, as well as clogging of the pavement over time will change the treatment performance of the pavement. These effects are part of ongoing investigations.

References

Drapper, D.W. 2000, Pilot study of pollutants in road runoff and evaluation of best management practices for south-east Queensland, PhD thesis, Griffith University.

Hogland, W., Niemczynowicz, J. & Wahman, T. 1987, 'The Unit Superstructure during the construction period', The Science of the Total Environment, vol. 59, pp. 411-424.

Niemczynowicz, J. 1990, 'Swedish way to stormwater enhancement by source control', in Urban stormwater quality enhancement: source control, retrofitting, and combined sewer technology. ASCE Urban Water Resources Research Council, pp. 156-168.

Pratt, C.J. 1990, 'Permeable pavements for stormwater quality enhancement', in Urban stormwater quality enhancement : source control, retrofitting, and combined sewer technology. ASCE Urban Water Resources Research Council, pp. 131-155.

Raimbault, G. 1997, 'French developments in reservoir structures', Sustaining Water Resources in the 21st Century: ASCE Conference proceedings, Malmo Sweden, pp. 212-228.

Rommel, M., Rus, M., Argue, J., Johnston, L. & Pezzaniti, D. 2001, 'Carpark with "1 to 1" (impervious/ permeable) paving: performance of "Formpave" blocks', in Proc. Novatech 4th Int. Conf. on Innovative Technologies in Urban Storm Drainage. Lyon, France. 25-27 June. pp.807-814

David Newton
Tel: (07) 3875 6679
Email: d.newton@mailbox.gu.edu.au

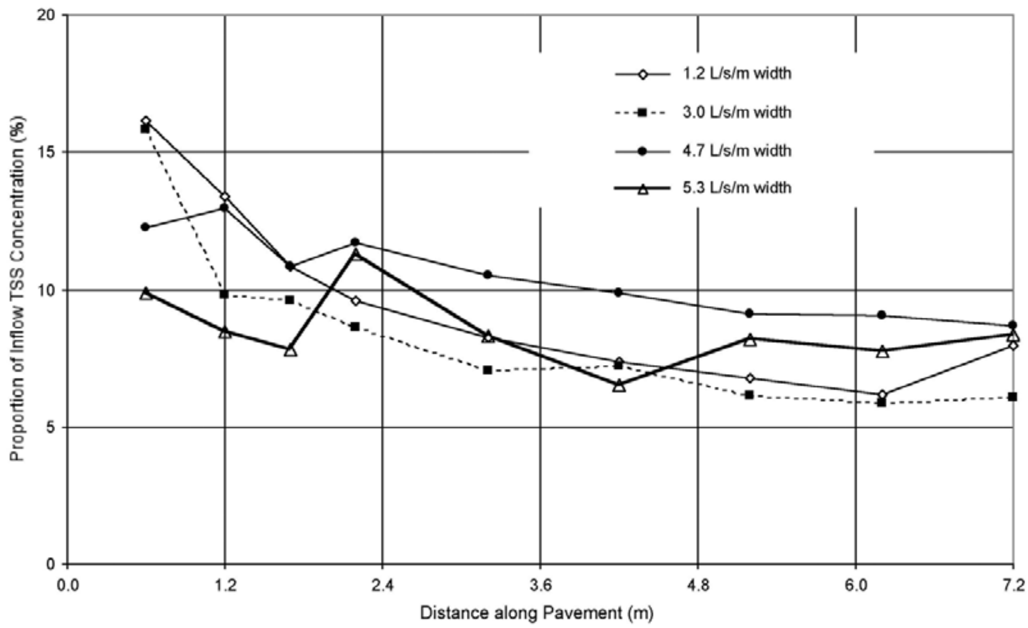


Figure 4. 2 Suspended Solids Removal by Experimental Porous Pavement

PROGRAM 5
CLIMATE VARIABILITY

Program Leader
FRANCIS CHIEW

Estimation of parameter values in hydrologic model for EMSS modelling

Francis Chiew

Hydrologic modelling in EMSS

The Environmental Management Support System (EMSS) is a software tool developed by the CRC for Catchment Hydrology to aid water quality management, in particular to assess the impact of changes in land use and land management practices on runoff and pollutant export loads. The EMSS is currently being established for regions in the focus catchments as part of the CRC for Catchment Hydrology development projects.

In the EMSS, daily runoff is estimated from rainfall and potential evapotranspiration data. Runoff from each sub-catchment is estimated as the weighted amount of runoff from the effective impervious area (with fixed impervious area model parameters), the 'forest' area and 'other pervious' area (proportions of each of the three land use types can be determined from land use maps). The lumped conceptual daily rainfall-runoff model, SIMHYD, is used to model the 'forest' area and 'other pervious' area. To apply the EMSS, parameter values for SIMHYD must be specified for all the sub-catchments in the modelling domain.

A workshop was held in Canberra in April 2003 to guide EMSS modellers in the focus catchments on the estimation of parameter values for SIMHYD and semi-automatic calibration of SIMHYD for EMSS modelling. This article describes the concepts behind the 'regional' calibration of SIMHYD, using the completed EMSS project for south-east Queensland as an example (see CRC for Catchment Hydrology Technical Report 02/01).

Hydrologic regions

The modelling area is divided into 'hydrologic regions'. The model calibration is carried out separately for each region to determine the one set of parameter values for each region that give good overall agreements between the modelled and recorded monthly streamflows at all the gauged catchments in the region. The optimised parameter values are then used for all the sub-catchments in the region for the EMSS simulations.

The "hydrologic regions" can be determined by using the drainage basin boundaries as a guide, examining the rainfall and runoff characteristics (and possibly other catchment characteristics) and ensuring that there are some gauged catchments in the region that can be used to calibrate the model. Figure 5.1 shows as an example the nine hydrologic regions for the south-east Queensland EMSS and the five to eight streamflow gauging sites in each region.

Model calibration for a hydrologic region

The model parameters are optimised to maximise an objective function defined as the sum of the Nash-Sutcliffe coefficient of efficiency (E) in all the gauged catchments in a region (an E value close to one indicates a good agreement between the monthly modelled and recorded flows). In addition, the objective function is penalised if the total modelled and recorded flows differ by more than 10% and/or if the modelled and recorded surface flow ratios (total surface runoff divided by total runoff) differ by more than 20% in any of the catchments. Realistic partitioning of the total runoff is important for the pollutant load modelling in the EMSS, because the pollutant concentrations in the surface runoff are much higher than the concentrations in the subsurface runoff.

The model simulations are also constrained to differentiate realistically between the forest area and other pervious area. This is best described by looking at the simulations resulting from the optimal set of parameter values for Region 8 in the south-east Queensland EMSS (see Figure 5.2). For example, the parameter values for INSC (interception store capacity) and SMSC (soil moisture store capacity) are higher in the 'forest' model than in the 'other pervious' model. The total runoff and the surface flow ratio (for the same rainfall) are also lower in the forest model than in the other pervious model (compare (e) and (f) in Figure 5. 2).

The high E values and the scatter plots in Figure 5.2 also indicate that the one set of optimised parameter values can estimate monthly streamflow satisfactorily in all the six catchments in the region. The total modelled flows are also within 10% of the recorded flows and there is generally good agreement between the surface flow ratios in the modelled and recorded flows (see (b) in Figure 5. 2).

The example shown here is for a hydrologic region that is relatively easy to calibrate. Nevertheless, although the calibration results may be poorer for other regions elsewhere in Australia, the regional calibration approach described here can be used to estimate a reasonable set of parameter values to apply on all sub-catchments in a region.

Francis Chiew
Tel: (03) 8344 6644
Email: fhsc@unimelb.edu.au

NEW TECHNICAL REPORT

Evaluation of Two Daily Rainfall Data Generation Models

by

Lionel Siriwardena
Ratnasingham Srikanthan
Tom McMahon

Technical Report 02/14

This report evaluates the Transition Probability Matrix model with Boughton's correction for interannual variability (TPM) and the simplified Daily and Monthly Mixed (DMMS) model for the generation of daily rainfall data. The report also compares the statistical characteristics of the daily, monthly and annual streamflow data simulated by a rainfall-runoff model using stochastic daily rainfall obtained using the TPM and DMMS models with the historical streamflow characteristics.

Printed and bound copies of this report are available from the Centre Office for $27.50 (includes GST, postage and handling).

Centre Office
tel 03 9905 2704
fax 03 9905 5033
email crcch@eng.monash.edu.au

NEW WORKING DOCUMENT

PREPARATION OF A CLIMATE DATA SET FOR THE MURRUMBIDGEE RIVER CATCHMENT FOR LAND SURFACE MODELLING EXPERIMENTS

by

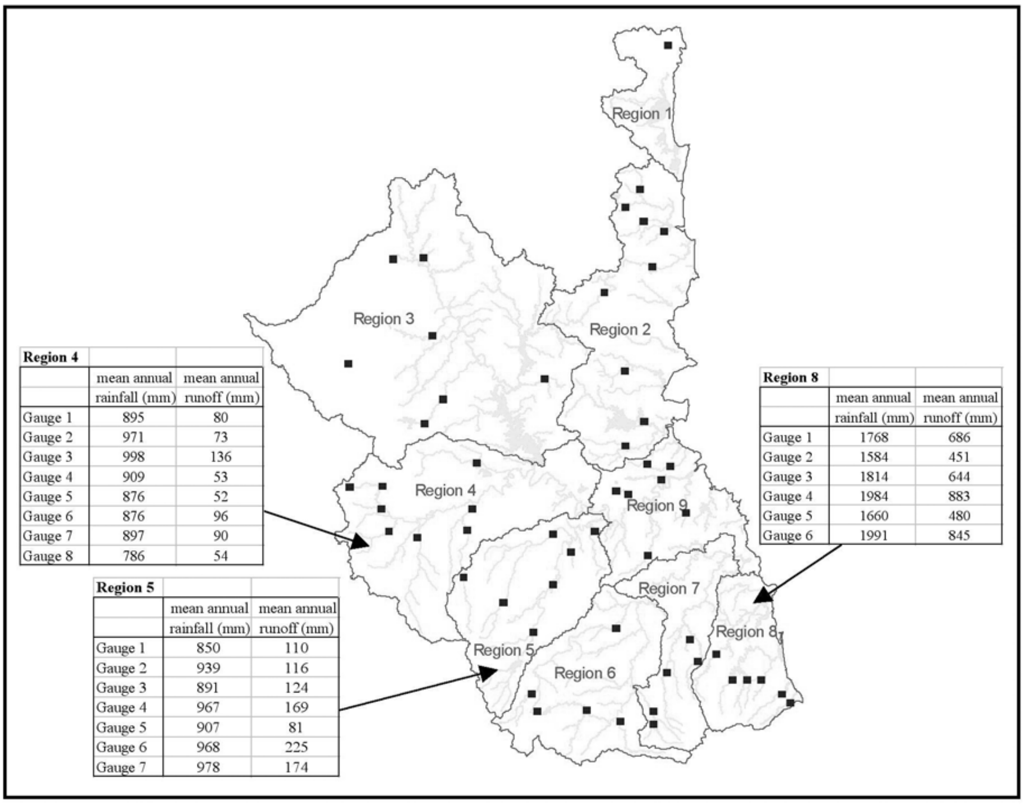
Lionel Siriwardena
Francis Chiew
Harald Richter
Andrew Western

Working Document 03/1

This report describes the preparation of a climate data set for ten locations in the Murrumbidgee River Basin: Balranald, Hay, Griffith, Yanco, West Wyalong, Cootamundra, Kyeamba, Adelong, Canberra and Cooma.

The data will be used as forcing data for land surface modelling experiments. The locations coincide with the sites in the CRC's Murrumbidgee River Basin soil moisture monitoring program.

Printed and bound copies of this working document are available from the Centre Office for $22.00 (includes GST, postage and handling) or an Adobe .pdf file can be downloaded at www.catchment.crc.org.au/publications



Region 4	mean annual rainfall (mm)	mean annual runoff (mm)
Gauge 1	895	80
Gauge 2	971	73
Gauge 3	998	136
Gauge 4	909	53
Gauge 5	876	52
Gauge 6	876	96
Gauge 7	897	90
Gauge 8	786	54

Region 5	mean annual rainfall (mm)	mean annual runoff (mm)
Gauge 1	850	110
Gauge 2	939	116
Gauge 3	891	124
Gauge 4	967	169
Gauge 5	907	81
Gauge 6	968	225
Gauge 7	978	174

Region 8	mean annual rainfall (mm)	mean annual runoff (mm)
Gauge 1	1768	686
Gauge 2	1584	451
Gauge 3	1814	644
Gauge 4	1984	883
Gauge 5	1660	480
Gauge 6	1991	845

Figure 5.1 Streamflow gauging stations and hydrologic regions in south-east Queensland

Parameter values for Region 8

	Forest model							Other pervious model						
	INSC	COEFF	SQ	SMSC	SUB	CRAK	K	INSC	COEFF	SQ	SMSC	SUB	CRAK	K
	2.100	200.000	1.500	320.000	0.100	0.300	0.140	1.500	200.000	1.500	260.000	0.500	0.500	0.300

Summary modelling statistics for Region 8

(a)	(b)				(c)					(d)	(e)		(f)	
Catchment	Comparison of modelled and recorded flows				Mean annual modelled values (mm)					Impervious	Forest		Other pervious	
	E	VOLR	SFR (mod)	SFR (rec)	Rainfall	Total runoff	Impervious area runoff	Forest area runoff	Other pervious runoff	runoff	SFR	runoff	SFR	runoff
146009A	0.93	0.93	0.47	0.58	1768	638	0	562	75	1557	0.44	625	0.67	745
146010A	0.96	1.09	0.55	0.51	1584	492	0	289	202	1384	0.47	445	0.66	578
146011A	0.95	1.01	0.50	0.52	1814	649	0	537	112	1583	0.46	630	0.68	758
146012A	0.93	0.96	0.54	0.45	1984	848	0	698	150	1802	0.50	831	0.71	939
146020A	0.96	1.10	0.52	0.54	1660	528	12	402	114	1449	0.46	497	0.66	628
146095A	0.91	0.98	0.52	0.52	1991	828	0	723	104	1773	0.49	816	0.70	923

(b) E is coefficient of efficiency, VOLR is ratio of total modelled flow on total recorded flow, and SFR is ratio of surface runoff on total runoff.

(c) tabulates the mean annual values of rainfall, total modelled runoff and runoff from the effective impervious area, forest area and other pervious area.

(d), **(e)** and **(f)** give the total runoff (and SFR for the forest model and other pervious model) if the catchment is 100% effective impervious, or forest or other pervious.

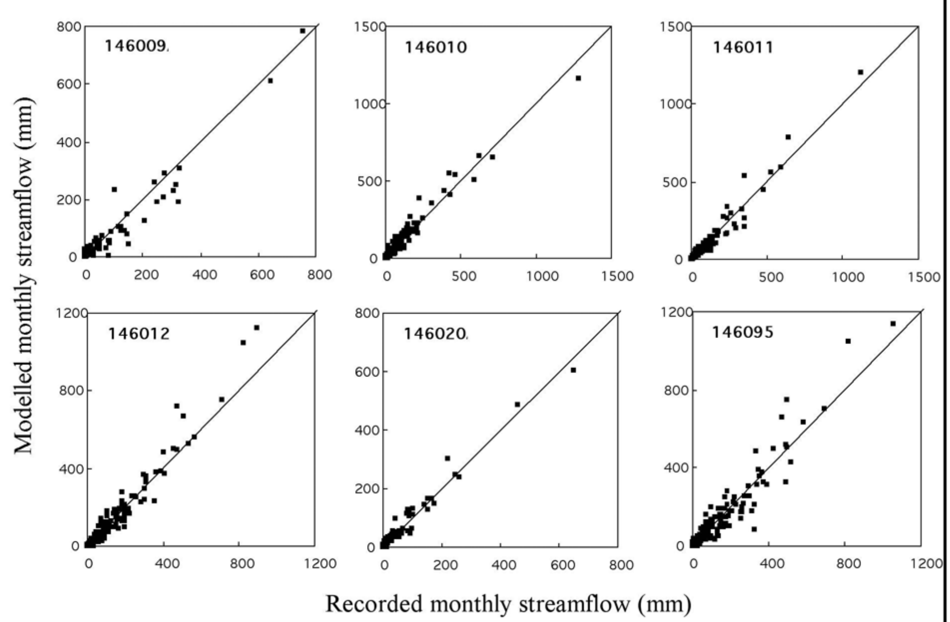


Figure 5.2 Summary of regional model calibration results for Region 8 in the south-east Queensland EMSS

PROGRAM 6

RIVER RESTORATION

Program Leader
MIKE STEWARDSON

Report by Brett Anderson, Ian Rutherfurd and Andrew Western

Flooding and riparian vegetation - how are they related?

Introduction

Re-vegetating of riparian zones and returning large wood to stream channels are widely practiced river rehabilitation techniques. Adding, or in many cases returning, vegetation to channels increases resistance to flow and as a result reduces the volume of water the channel can carry without flooding. A major aim of traditional river management practices, such as stream cleaning and channelisation, is to increase the carrying capacity of the channel so that over-bank events occur less frequently. These practices are effective in reducing the incidence of flooding locally in the 'cleaned' or channelised reach, with this 'flood protection' provided by increasing the velocity of the flow at a given stage.

However, if planned rehabilitation works are extensive, affecting a significant proportion of the stream network, the simple reach-scale perspective above is incomplete. Because water passes more slowly down revegetated reaches, the hydrograph timing is delayed and the peak discharge is in general attenuated. This attenuation of the hydrograph reduces the discharge that the channel has to carry, compensating in whole or in part for the reduction in the bankfull capacity of a revegetated channel. Therefore, we argue that the impact of extensive rehabilitation work on flood susceptibility is a trade-off between local and upstream effects, and that it is necessary to take a catchment-scale view to predict the net impact at a given reach.

Vegetal resistance effects on the hydrograph

Previous numerical investigations demonstrate that increased channel roughness attenuates the peak discharge at the catchment outlet and delays the arrival of the hydrograph peak (Rutherfurd *et al.*, 1996; Wolff and Burges, 1994; Woltemade and Potter, 1994). Sensitivity to channel network roughness was examined in these studies by perturbing the value of the roughness coefficient (e.g. Manning's n) around a mean value. These results are applicable to rivers where the value of resistance can be considered constant with stage, albeit with different values assigned for in-channel and floodplain roughness. Such an assumption is not valid for vegetated waterways where roughness changes with stage (e.g. Darby, 1999; Helmio, 2002; Jarvela, 2002). We present some results from a numerical investigation that show how flood wave translation changes under the imposition of a depth-variable flow resistance environment. The investigation addressed the following questions:

- does vegetal roughness appreciably change the speed and/or shape of flood waves;
- does the impact of vegetation vary with hydrograph size or with the relative size of vegetation compared to the channel; and,
- what do these results mean in the context of river rehabilitation?

Methodology

Flood waves were routed with a one-dimensional, unsteady flow model down a reach comprising a main channel with flood plains on either side (Figure 6.1). The resistance characteristics of the channel were varied to simulate the presence of riparian vegetation. The vegetation present in the riparian zone is defined using two simple properties: canopy height and foliage density, and by the variation of these properties across the cross-section. Figure 6.2 depicts the form of roughness variation assumed for a vegetal unit. (The effect of the distribution of such units integrated over the cross-section yields the desired Manning's n variations for the channel and floodplains.) In this article, results are presented for four vegetation scenarios based on canopy heights (CH) of 0m (no vegetation), 0.5m, 1.5m, and 3.0m. (A detailed description of this algorithm has been accepted for presentation at the upcoming ModSim 2003 Symposium and will be published as part of the proceedings.)

Results

Flood hydrographs with return periods ranging from 2 years to 100 years (peak discharges from 295 to 816 cumecs) were routed through the reach using a numerical procedure. The impact of vegetal roughness on hydrographs of different sizes is exemplified by the results in Figure 6.3. This figure shows the shape of a small and a large flood (2yr and 100yr ARI) after 60km of routing under the four roughness scenarios. Differences in arrival times, in hydrograph shape and attenuation of the peak discharge are evident. Changes in the arrival time are more pronounced for the small flood hydrograph, whereas attenuation of peak discharge is larger for the larger flood. The steepness of the rising limb varies, with the smaller flood flattening out considerably under all but the 'Tall Veg' scenario (Figure 6.3).

URBAN STORMWATER SOFTWARE

MODEL FOR URBAN STORMWATER IMPROVEMENT CONCEPTUALISATION (MUSIC)

MUSIC is a decision-support system. The software enables users to evaluate conceptual designs of stormwater management systems to ensure they are appropriate for their catchments. By simulating the performance of stormwater quality improvement measures, music determines if proposed systems can meet specified water quality objectives.

MUSIC is available from the Centre Office for $88.00

Individuals will need to sign a Licence Agreement (available from the Centre Office and website: www.catchment.crc.org.au)

For further information contact the Centre Office on 03 9905 2704 or email crcch@eng.monash.edu.au

Please note: MUSIC version 1.00 is a development version and will be valid until June 2003. The CRC for Catchment Hydrology is committed to updating MUSIC annually until at least 2006. Subsequent versions of MUSIC may be charged for.

The simulation results demonstrate that the speed and peak discharge of flood waves are appreciably affected by vegetal roughness. In addition, our investigation shows that the changes are sensitive to the magnitude of the flood and also to the height of vegetation. Based on an expanded set of simulations, where additional parameters such as reach slope and vegetation density were varied, we have developed a quantitative model that modifies flood wave routing to account for the vegetal properties through a reach. Our next step is to incorporate this model into our catchment-scale flood routing software. This software will have the capability to investigate the trade-off between local decreases in the bankfull capacity of a channel and attenuation of the response of the upstream channel network.

Implications for catchment managers

The size of a flood event is primarily driven by how much water falls from the sky - a factor beyond the control of the best catchment managers. Important factors that are controllable include storages (dams) and the condition of the channel network. Building storages is a proven method for reducing the severity of flood events, and at the same time imposes many well documented negative impacts on stream health and fluvial function associated with regulated flows. Rehabilitation of channels almost inevitably involves introducing roughness elements to channels, ideally along long stretches of highly impacted streams. Our research shows that the impact of rehabilitation works can only be properly assessed if a catchment-scale view is taken. Perhaps the most important message is that additional channel roughness need not be detrimental to flood response, instead this research suggests that carefully designed upstream revegetation works are capable of reducing flood risk in flood-prone reaches.

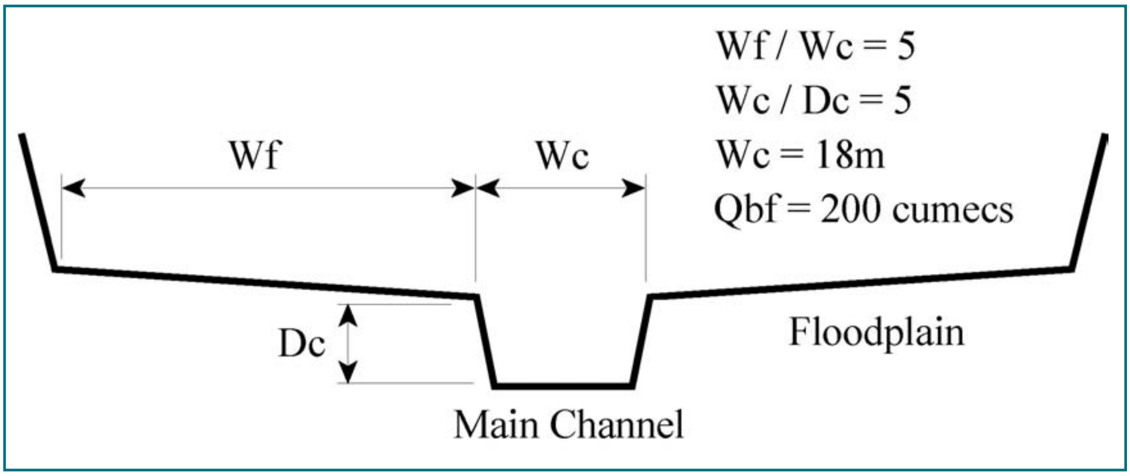


Figure 6.1. Cross-section schematic with dimensions (Qbf = bankfull discharge).

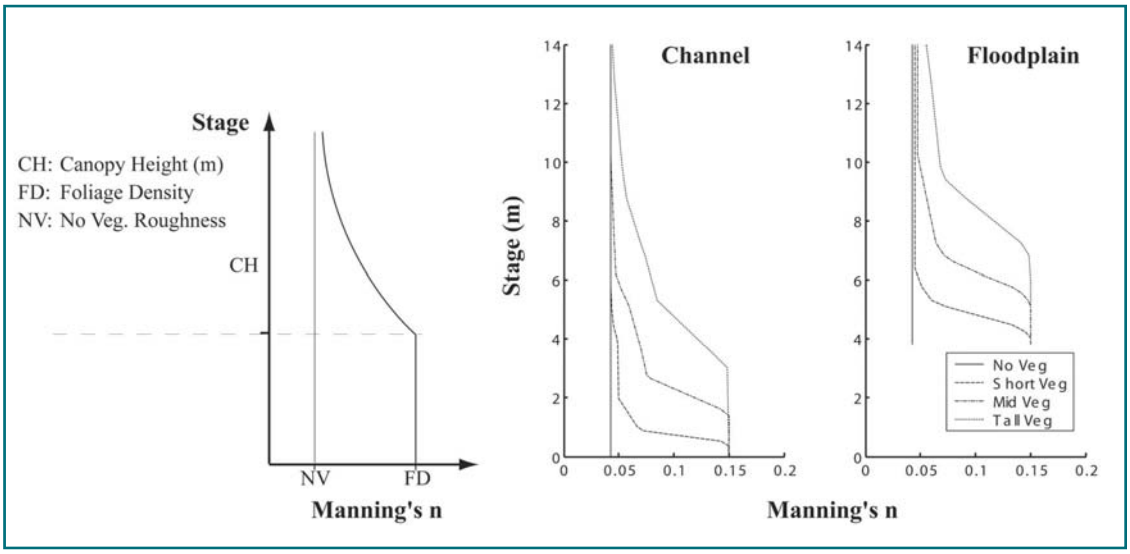


Figure 6.2. Model of the depth variation of vegetal roughness with flow stage for a plant unit (left) and integrated across the main channel and floodplain (right) for four vegetation scenarios.

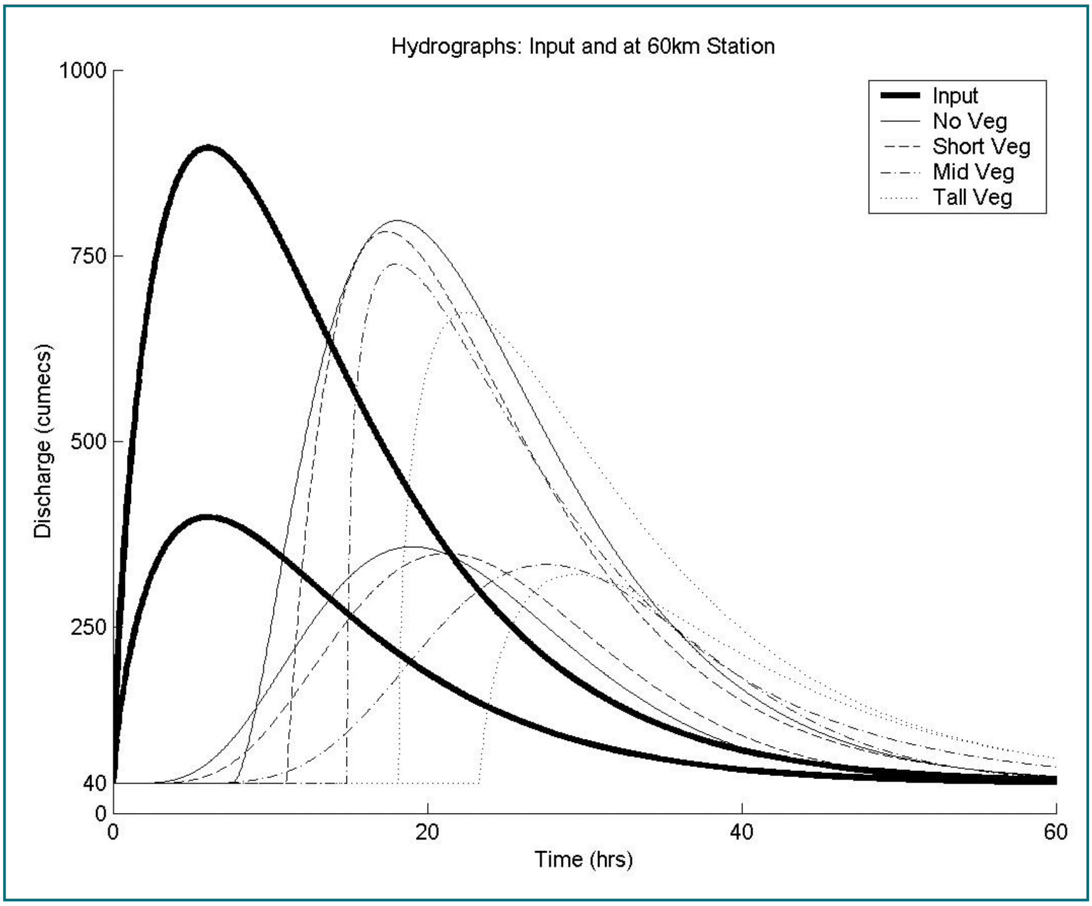


Figure 6.3. Selected input hydrographs (2yr and 100yr ARI) and the corresponding fitted hydrographs at 60km downstream for each vegetation scenario.

References:

Darby, S.E., 1999. Effect of riparian vegetation on flow resistance and flood potential. Journal of Hydraulic Engineering, 125(5): 443-454.

Helmio, T., 2002. Unsteady 1D flow model of compound channel with vegetated floodplains. Journal of Hydrology, 269(1-2): 89-99.

Jarvela, J., 2002. Flow resistance of flexible and stiff vegetation: a flume study with natural plants. Journal of Hydrology, 269(1-2): 44-54.

Rutherfurd, I.D., Hoang, T., Prosser, I., Abernethy, B. and Jayasuriya, N., 1996. The impact of gully networks on the time-to-peak and size of flood hydrographs, 23rd Hydrology and Water Resources Symposium. Institution of Engineers, Australia, Hobart, Australia, pp. 397-403.

Wolff, C.G. and Burges, S.J., 1994. An analysis of the influence of river channel properties on flood frequency. Journal of Hydrology, 153(1-4): 317-337.

Woltemade, C.J. and Potter, K.W., 1994. A watershed modeling analysis of fluvial geomorphologic influences on flood peak attenuation. Water Resources Research, 30(6): 1933-1942.

Brett Anderson
Tel: (03) 8344 3947
Email: b.anderson5@pgrad.unimelb.edu.au

Ian Rutherfurd
Tel: (03) 8344 7123
Email: idruth@unimelb.edu.au

Andrew Western
Tel: (03) 8344 7305
Email: a.western@unimelb.edu.au

OTHER OUTLETS FOR CRC PUBLICATIONS

In addition to the Centre Office, all CRC publications are available through the Australian Water Association (AWA) Bookshop in Sydney and the Department of Sustainability and Environment (DSE) Resource Centre in Melbourne. AWA and DSE also stock a wide range of other environmental publications.

AWA Bookshop (virtual)
contact Diane Wiesner
Bookshop Manager
tel: 02 9413 1288
fax: 02 9413 1047
email: bookshop@awa.asn.au
web: www.awa.asn.au/bookshop/

DSE Resource Centre
8 Nicholson Street (cnr Victoria Parade)
PO Box 500
East Melbourne
Victoria 3002 Australia
publication.sales@nre.vic.gov.au
Phone: 03 9637 8325
Fax: 03 9637 8150
www.nre.vic.gov.au
Open: 8.30-5.30, Monday to Friday

WHAT'S HAPPENING WHEN?

FIND OUT ABOUT CRC ACTIVITIES BY EMAIL

THE CRC WILL NOTIFY YOU OF AN UPCOMING CRC ACTIVITY IN YOUR AREA OF INTEREST

You can register to receive this information on line at www.catchment.crc.org.au/subscribe

or you can contact Virginia Verrelli at the Centre Office on 03 9905 2704.

EDUCATION AND TRAINING PROGRAM

Program Leader
TIM SMITH

Education and Training - Current Initiatives

At a glance - a summary of this article

This article provides an overview of some of the current initiatives of the Catchment Hydrology CRC Education and Training Program (Program 8). Specific items discussed include the recent Education and Training workshops for researchers, and the upcoming Respect, Reflect & React Symposiums and Catchment Modelling School.

Education and Training workshops

The CRC for Catchment Hydrology is committed to the adoption of the integrated modelling toolkit currently being developed. Education and training is a core component of the adoption process. Program 8 provides a comprehensive whole-of-CRC framework for education and training including methodologies for designing, piloting, delivering, brokering and evaluating education and training activities. These objectives are achieved through the utilisation of resources including templates for workshop planning and evaluation and train-the-trainer resources for researchers who intend to conduct education and training activities.

In order to assist researchers in the design, conduct and assessment of education and training activities, Tim Smith, James Whelan and Nick Murray ran a series of half-day workshops in Brisbane, Melbourne and Canberra in March and May 2003.

The objectives of the Education and Training Workshops were to:

- Provide an overview of education and training in the CRC
- Improve participants' understanding of train-the-trainer techniques and principles
- Inform the development of tutorials
- Improve participants' understanding of education and training tools
- Inform the development of the Catchment Modelling School

The Education and Training Cycle (Figure 8.1) underpinned the workshops and refects the CRC's approach to education and training - planning, acting, and reflecting. Figure 8.1 also shows the ways in which Program 8 supports education and training across the CRC.

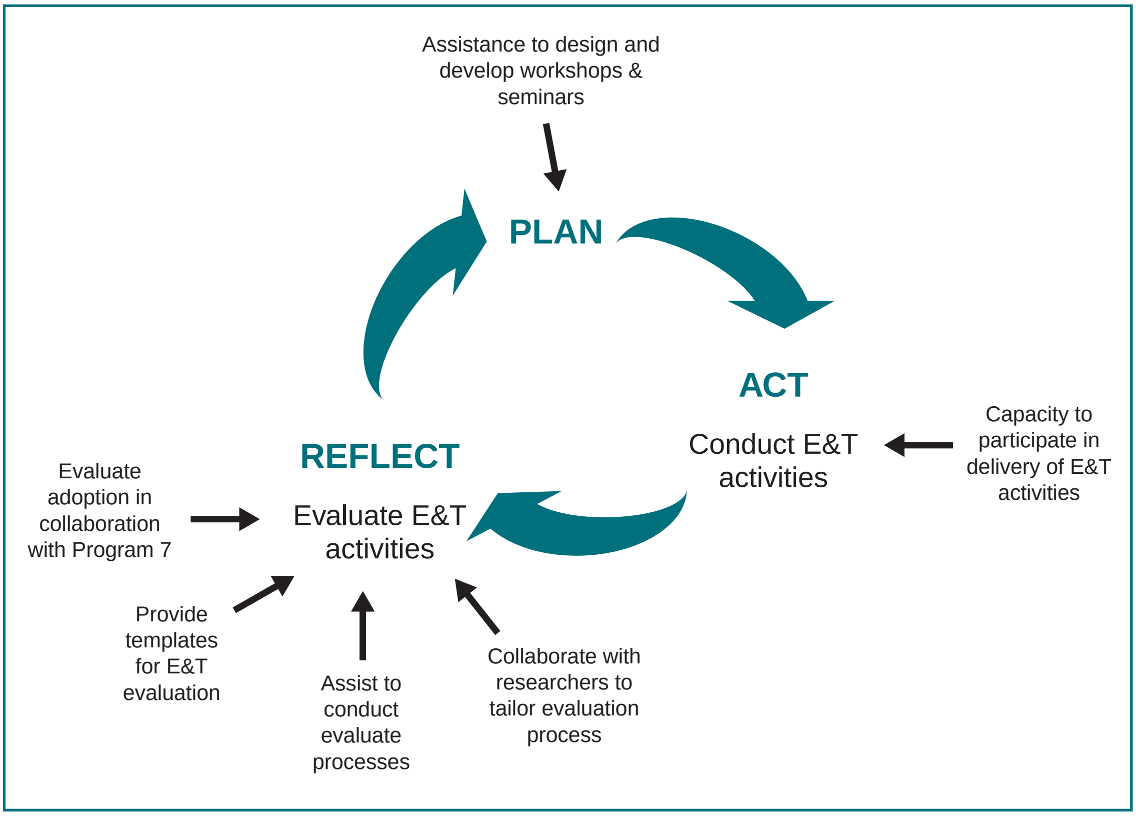


Figure 8.1: The CRC for Catchment Hydrology Education and Training Cycle

Most participants were able to work through actual education and training activities that they were planning - using tools and templates developed by Program 8 (available on CD).

Participant feedback was generally very positive, with an average score of 4.5 out of 5 for facilitation, 4.6 out of 5 for content and structure, and 4.3 out of 5 for application (expected influence on their approach to education and training). As one participant stated '...solid information to help us plan and consider the content and delivery of our own workshops'. Information gained from the workshops will also be used to design tutorials and the Catchment Modelling School planned for February 2004.

For more information contact Tim Smith <T.Smith@griffith.edu.au>.

Reflect, Respect & React 2003 Symposium Series: Social Solutions for Environmental Futures
Brisbane, Canberra, Melbourne and Emerald
27 September to 2 October 2003

Respect, Reflect & React 2003 Symposium Series is designed to foster and support an analysis of the various efforts to facilitate change for healthy environments in Australia. The Series will showcase the CRC for Catchment Hydrology's social science research over the last three years. Each forum will provide opportunities to hear and learn from practitioners and researchers as they share their experience and understanding of different approaches to social and environmental change. The symposium series will be relevant to CRC for Catchment Hydrology industry participants, namely Queensland Department of Natural Resources and Mines (QDNRM), New South Wales Department of Infrastructure, Planning and Natural Resources (DIPNR), Victorian Department of Sustainability and Environment (DSE), Goulburn-Murray Water (GMW) and the Murray-Darling Basin Commission (MDBC), as well as others in government and non-government organisations engaged in planning and managing changes that contribute to healthier environments.

Symposium Series Locations/Dates are:

- Brisbane
  EcoCentre, Griffith University, Nathan Campus
  Saturday 27 September 2003, 9.30am-4.30pm

- Canberra
  University House, Australian National University
  Monday 29 September 2003, 9:30am-1:30pm

- Melbourne
  Graduate Centre, University of Melbourne
  Tuesday 30 September 2003, 9:30am-1:30pm

- Emerald, Qld
  Emerald Agricultural College conference room
  Thursday 2 October 2003, 10:00am-1:00pm

For more information contact James Whelan <james.whelan@griffith.edu.au>.

Catchment Modelling School - February 2004

The CRC for Catchment Hydrology's premier education and training event for 2004 will be the Catchment Modelling School. A range of models will be showcased at the Catchment Modelling School, relating to urban stormwater management, water trading, and river restoration, as well as many other issues affecting catchment management. The purpose of the Catchment Modelling School is to underpin the adoption of the integrated modelling toolkit through education and training on the use and application of CRC products.

The specific objectives of the Catchment Modelling School are to:

- Train users in the application of the toolkit products
- Promote the integrated modelling capacity of the CRC
- Promote the individual products of the toolkit

The Catchment Modelling School will be of direct relevance to the CRC for Catchment Hydrology industry participants and many others including water allocation modellers, water quality modellers, water policy makers, water economists, ecologists, technical government personnel, and consultants.

The Catchment Modelling School is being planned for February 2004.

Tim Smith
Tel: (07) 3875 5176
email: t.smith@griffith.edu.au

REFLECT, RESPECT AND REACT 2003 SYMPOSIUM SERIES

SOCIAL SOLUTIONS FOR ENVIRONMENTAL FUTURES

27 September to 2 October 2003

Brisbane
EcoCentre, Griffith University
Saturday 27 September 2003, 9.30am-4.30pm

Canberra
University House, Australian National University
Monday 29 September 2003, 9:30am-1:30pm

Melbourne
Graduate Centre, University of Melbourne
Tuesday 30 September 2003, 9:30am-1:30pm

Emerald
Thursday 2 October 2003, 10:00am-1:00pm

For more information contact James Whelan james.whelan@griffith.edu.au

POSTGRADUATES AND THEIR PROJECTS

Marnie Griffith

I'll be perfectly frank: I got into the CRC for Catchment Hydrology not through some long-held, deep-seated interest in catchment hydrology, but because I wanted to do further study but didn't want to do 'just economics'. I was particularly interested in comparing the value theory underlying economics (most economists will deny there is one, but don't be fooled...) with environmental philosophies. Having quantitative-based first degrees (economics and science), but feeling it wasn't really my strength, I was also determined not to do anything numerical. When the CRC opportunity came up I thought great, a bit of environment, a bit of economics, plus the potential to do something applied and policy relevant.

Well, even the best laid plans, etc. I've ended up (entirely through my own volition) with a modelling-based project with no 'environment' and an awful lot of farms and channels. But at least I kept the policy focus.

Basically my project considers how effective the COAG water policy reforms, responsible for such sweeping institutional changes as environmental flow allocations and formal markets for water, are likely to be in the face of the need to make decisions under uncertainty.

The COAG reform package is a product of the times: it not only attempts to take into account all the myriad factors that are part and parcel of water resource management, but also to reallocate the resource in an efficient way. For economists, this would tend to involve not command and control reallocation from on-high, but putting in place mechanisms and incentives which reveal true values for water and automatically redistribute on the basis of these.

Irrigated agriculture accounts for the lion's share of water use in Australia, and redistributing any significant amount of water is going to involve farmers. The mechanism the COAG reforms introduced to reallocate rights to water held by agriculture is the water market. The idea is that by showing what other farmers (or others able to trade in the water market) are willing to buy or sell water for, i.e. revealing their valuations for water, and making the property rights tradeable, water will move around to the most efficient uses, automatically and painlessly, because it will be in those farmers' own best interests. (Trade is restricted if it is considered that the farmers' best interests do not coincide with the nation's, e.g. for environmental or social reasons, or to protect the viability of existing water infrastructure.)

There are strong assumptions underlying this reasoning. These can basically be summarised as:

(a) farmers know the value of water, to themselves and to other users (perfect information);

(b) they will act to maximise the returns they get from their water (they are profit maximisers).

There are many reasons why farmers may not act to maximise the value of their water. Maybe they are satisfied with the returns they currently get; maybe they perceive that changing from the old ways is too great an effort; maybe they are planning on packing up and leaving in a few years, and want to leave the decision about the farm to their successors. That said, I will be assuming that farmers do care solely about farm business returns over a given period, in order to concentrate more on assumption (a).

Irrigated agriculture is an inherently risky business. There are many uncertainties which mean that farmers will not in fact know their own value for water. These include three of the most notoriously volatile quantities in existence: the weather, commodity prices and government policy. In addition, it is not likely farmers would know at what price other potential buyers or sellers value water and especially how this may change through time. But this information is necessary for them to make strategic decisions that make the best use of water.

While I will be assuming that farmers care only about returns over a given period, they won't know what these returns are going to be when they have to make critical decisions. I will formulate likely scenarios for how farmers form beliefs about the uncertainties they face, and how they make decisions given those beliefs, with the aim of seeing how that changes the reallocation of water compared to the perfect information, risk-neutral base case which the COAG reforms assume. I hope this will give some insight into why predictions of sweeping structural change to date have disappointed, and possible implications for future behaviour.

I found most of my first year very tough. I can see now why there is more talk than action to the 'integrated' approach. It's hard yakka climbing those steep learning curves, and going from relative expertise to relative ignorance means putting your ego at risk. It has been a frustrating, humbling experience. But enough whingeing: ultimately it has also been a rewarding experience. Though it didn't turn out quite the way I planned, I now think with satisfaction about how much I have learnt about the water requirements of perennial pastures and travel times for dam releases from Lake Eildon, and I'm happy with my choice.

Marnie Griffith
Tel: (03) 9905 5022
Email: marnie.griffith@eng.monash.edu.au

CRC PROFILE

Our CRC Profile for June is:

Mark Sallaway

I still get the question 'What's a nice Agricultural Scientist like you doing in a Water CRC?' It is surprising I suppose, but I think it reflects the way our scientific community has become much more holistic and uses a systems approach to address major issues of the day.

Ancient History

Having graduated from the University of Queensland in Ag Science in the late 60's I headed for the Northern Territory. I had won a cadetship with the Northern Territory Administration, part of the then Department of Interior of the Commonwealth Government. This was in the days before independence! This was a great opportunity for a young scientist as I was literally thrown in the deep end of the wild frontiers. The Northern Territory was an area where new activities were being undertaken and new ideas were being trialled. Some may remember the great adventures and failures of the Humpty-do rice farms or the Ord River scheme. Having graduated as a well-qualified soybean agronomist I was naturally put into the land resource survey group in Primary Industries. This was in the days of the CSIRO-led regional resource surveys which provided a platform for understanding our landscapes for further development. In those days development was not a dirty word!

Having served an apprenticeship with some notable leaders in the Douglas and Daly River catchments, I was moved down to the Alice as the District Soil Conservation Officer. This was a particularly exciting time as the position was based at the Arid Zone Research Institute where a mixture of CSIRO and Primary Industries staff worked together on a broad range of issues ranging from dingoes to a blossoming grape-growing industry. The soil conservation effort was largely targeted at a major project to stabilise the areas surrounding the airport so that dust storms would not interfere with aircraft movements or with regeneration projects on individual properties. The Alice Springs district had just come out of a severe drought and extensive areas of the rangelands were severely denuded. This was my first introduction to the combination of water and landscape management. In this arid environment I began to appreciate that, while the answers may lie in the soil, it was very much driven by the flow of water.

One of the interesting exercises of this time was a survey of Ayres Rock- Mt Olga as a precursor to the development of this area. This also involved reclamation of the area surrounding Ayres Rock where the ring road had modified the natural water flows in the landscape, resulting in either erosion or droughting and death of the natural mulga groves.

Having met a young teacher and committed to a life together I accepted that we may have to move to a more 'civilised' area. In the late 1970s I moved to the Mackay district as a research officer looking at land-use aspects in the sugarcane industry. This was in a boom period where the sugar industry was looking to expand on to every piece of available land. This resulted in many unsuitable areas being developed causing severe soil erosion and an unsustainable sugar industry. It was at this time that I completed my post graduate studies with Griffith University on land degradation in the sugar industry in a tropical environment. Having gone from a arid zone to a tropical rainfall zone I finally had to face the question of waterflow. It was at this stage that I first undertook measurement of waterflow and sediment collection at a farm or paddock scale. In hindsight, it was not a great success.

Having cut my teeth in an intensive agricultural industry trying to examine the effects of land management on modifying land degradation, I moved to the grain growing area of Emerald to study farming systems at a farm scale. This was also an exciting time as technology was rapidly advancing. Combined with the knowledge from the past we had more sophisticated runoff measuring devices and new fandangle electronic measuring equipment. The high-powered 8K loggers enabled us to actually monitor an event at fine (5 minute) intervals. The data was retrieved by a portable computer (if you call a 500x500x250mm box portable). This computer allowed us to extract and view the data from the logger following an event. For the first time we tried to relate landscape characteristics to the flow being generated and the sediments it was extracting. With the advent of the PC we were actually able to start looking at modelling tools to relate these factors.

Following the successes in understanding tillage effects on various crops on the runoff process I moved to another sugar growing area, Bundaberg. However my initial studies involved grazing - land management in conjunction with the CSIRO and a DPI research group based in Rockhampton. Trial sites at the Narayan

Research Station (CSIRO) and the Galloway Plains (DPI) examined the effects of grazing management on runoff generation from plot to the landscape scale. These efforts were a challenging and fascinating period as both projects involved large, multidisciplinary teams who were working together in a systems approach to try to gain an understanding of how to manage landscape for sustainable development. The progress of both these projects is now on the record and has helped the grazing industry better understand how it can survive in the subtropics.

The last period in the 1990s has been involved with a move back, full cycle, to the sugar industry. However this time with improved understanding of landscaping behaviour, we have been studying nutrient and pesticide movement from plot to whole catchment scale. This has come at a time when the general population is much more aware of environmental matters and industries are reacting to this concern by modifying their management practices to minimise offsite effects. This joint sugar industry- ACIAR project has resulted in a better understanding of how we manage our sugar lands and has been particularly beneficial with the recent concerns of the Great Barrier Reef.

Having had so much fun in the field and enjoying my practical research work I have had to pay a price. My current activities largely revolve around a computer and a desk as I try to oversee the Departmental research in South East Queensland. This is an interesting period as the role of Science is increasingly valued, but the resources are diminishing. Much of the activity involves filling a 'broker role' and great emphasis has been placed on cooperative activities. It is well recognised that no one organisation can hope to obtain all the answers and hence my departments strong involvement in the CRC for Catchment Hydrology. It is through cooperative effort that we are looking to address some of the pressing environmental issues of South East Queensland.

Mark Sallaway
Tel: (07) 4131 5850
Email: mark.sallaway@dnr.qld.gov.au

WHERE ARE THEY NOW?

Report by Juliette Woods

Everything's Bigger in Texas

For the past couple of years, I've been working at the University of Texas in Austin and I have to tell you that what they say about Texas is true - of the Austin campus at least. There are fifty thousand students attending my place of work and twenty-two thousand staff. Yes, UT-Austin has the same population as Ballarat or Darwin.

It has its own police, its own bus system, its own currency ('Bevo bucks'), an eighty-thousand capacity football stadium, seventeen libraries, four theatres, eight museums and galleries, ten gyms, a forty-foot-wingspan Quetzalcoatlus northropi pterosaur and a personal set of oil wells. UT struck oil some decades back and this has funded, among other things, a major building program, more academic chairs than I care to count, and the purchase of such bagatelles as the papers of Keats, Lawrence, Joyce and, most recently, the Watergate scandal. What's more, many of UT's graduates have gone on to strike oil themselves and have been very generous to their alma mater since. The building I work in was paid for by a Dallas philanthropist, one who didn't even attend UT, and it's all wide, white corridors and wireless Internet. The lunchroom looks out over a vista of sun-baked, red-roofed buildings, spreading live-oaks and heat-addled squirrels.

The facilities aren't half bad either. I work for the Computational Fluid Dynamics Lab, running computer simulations of groundwater flow on their baby 16-node cluster or, when I need it, UT's 128-processor machine 'Longhorn' (named after a distinctive local breed of cattle). My colleagues are mostly rocket scientists, more or less, as the CFDLab is part of the Department of Aerospace Engineering and Engineering Mechanics. A funny place to be running groundwater simulations, you might think, but the mathematics of groundwater flow is not too dissimilar from the mathematics of air flow around aircraft or the behaviour of fluids in space and the computer code we use can simulate all of these types of problem. The lab is interested in the more theoretical aspects of simulation - whereas I have a pretty good practical understanding developed through working with the SA state government, consulting firms, CSIRO and the CRC - so I've been trying to apply this theoretical bent to areas with hydrogeological applications, like the spread of saline waters through aquifers. It's been a two-way education as I learn more about finite elements and error indicators while I teach my colleagues about the difficulties of modelling field sites and what I mean when I say the results look 'bonza'.

But in a few short weeks I'll be back in Australia for the first time since the move to Austin, initially to teach part of a parallel computing workshop in Perth and then to give a talk at the International Congress on Industrial and Applied Mathematics in Sydney. My partner and I could head back to Texas afterwards, but we've decided to take a punt and try and find work back in Australia instead. We had a Texas-sized scare late last year, when my partner was diagnosed with cancer, and although his radiotherapy and chemotherapy were successful, we'd like to stay closer to friends and family now. So we're packing up our books, eating our last quesadillas, and turning our thoughts to McLaren Vale wine and eucalypt-scented air. And anyway, Australia's bigger than Texas. We just don't tell many Texans so.

Juliette Woods
Email: jwsoods@cfdlab.ae.texas.edu

COOPERATIVE RESEARCH CENTRE FOR

CATCHMENT HYDROLOGY

Print Post Approved
PP338685/00026

If undelivered return to:

Department of Civil Engineering
Building 60
Monash University
Vic 3800

SURFACE MAIL

POSTAGE PAID AUSTRALIA

CENTRE OFFICE:
CRC for Catchment Hydrology
Department of Civil Engineering
Building 60 Monash University,
Vic 3800
Telephone: +61 3 9905 2704
Facsimile: +61 3 9905 5033

crcch@eng.monash.edu.au

OUR MISSION

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

OUR RESEARCH

To achieve our mission the CRC has six multi-disciplinary research programs:

- Predicting catchment behaviour
- Land-use impacts on rivers
- Sustainable water allocation
- Urban stormwater quality
- Climate variability
- River restoration

CRC AUSTRALIA

The Cooperative Research Centre for Catchment Hydrology is a cooperative venture formed under the Commonwealth CRC Program between:

Brisbane City Council
Bureau of Meteorology
CSIRO Land and Water
Department of Infrastructure, Planning and Natural Resources
Department of Sustainability and Environment, Vic
Goulburn-Murray Water
Griffith University
Melbourne Water
Monash University
Murray-Darling Basin Commission
Natural Resources and Mines, Qld
Southern Rural Water
The University of Melbourne
Wimmera Mallee Water

Associates:
Water Corporation of Western Australia