NEWSLETTER OF THE COOPERATIVE RESEARCH CENTRE FOR CATCHMENT HYDROLOGY

CATCHWORD

NO 92 MARCH 2001

A NOTE FROM THE DIRECTOR

Professor Russell Mein

Inside...

COOPERATING COOPERATIVE RESEARCH CENTRES

It is just ten years this month since the successful applicants for the First Round of the CRC Program were announced. Since then, seven application rounds have been completed, with the CRC for Catchment Hydrology being successful in the Second and Sixth of these.

It has been a successful model for cooperative research, and is so regarded by the Commonwealth. In the recent innovation statement *Backing Australia's Ability*, the government committed an extra $225m over the next five years, bringing the total projected expenditure by the Commonwealth on its CRC Program to $947m for that period. [Guidelines for the expanded program - whether it is for more CRCs, or more for existing CRCs to increase their range of activities, or whatever – are to be provided later in the year].

In the latest selection round, nineteen applications (from existing CRCs or new groups) were successful in their bids for a seven-year funding term. These are listed on the web at www.isr.gov.au/crc for those interested. Three of them would appear to have particular relevance to ours.

(i) The CRC for Water Quality and Treatment. We have had a close working relationship with this CRC in its previous life, particularly through the Water Forum (the informal grouping of the five water CRCs). This link is expected to be closer in the new round through their interest in tracking pathogens in catchment runoff. We have been involved with them already in some cooperative activity in this area.

(ii) The CRC for Plant-Based Management of Dryland Salinity. This is a new CRC, aiming to help manage dryland salinity through the use of farming systems that mimic more closely the (former) natural ecosystem. There are many aspects to this (including economic), but the one of most interest to us is the water-use characteristics of the land-cover they propose; the possibilities are for us to collaborate with them to evaluate the impact of new plant-types in our catchment-scale modelling. Initial discussions along these lines have been very positive, and are being pursued. The potential for fruitful outcomes seems large.

(iii) The CRC for Landscape Environments and Mineral Exploration (LEME). In its former life, the first 'E' in LEME stood for 'Evolution'; the change to 'Environments' signifies the intended application of developments in airborne geophysical methods. These include the capability to determine salt concentrations in groundwater layers to depths of more than 100 metres. There is potential to use such information in catchment-scale models to assess salinity hazard for a range of future scenarios; it's an exciting prospect we'll be following up in the coming months.

It is appropriate to remind *Catchword* readers of the strong links we have with two CRCs that were funded (like us) in the Sixth Selection Round – the CRC for Freshwater Ecology, and the CRC for Coastal Zone, Estuary, and Waterway Management.

We have several joint projects running with the CRC for Freshwater Ecology, enabling research which brings together our complementary strengths in catchment hydrology and freshwater ecology. Most of these occur in the River Restoration and the Urban Stormwater Quality Programs, where the joint activity is particularly beneficial in providing integration of research disciplines (eg ecology, geomorphology, hydrology).

Our links with the CRC for Coastal Zone, Estuary, and Waterway Management are similarly strong. On the research side, it is logical that we should liaise to ensure that our predictions of water quality and quantity are compatible with their requirements for studies of coastal impacts. In our Education and Training Programs, we have the same Program Leader, and share a Project Leader; this arrangement has certainly been an enhancement to both CRCs.

CRCs are (by definition) cooperative, especially with their constituent Parties. In our experience, this cooperation can (and should) extend to other CRCs, particularly where there are beneficial outcomes with manageable overheads. The CRC for Catchment Hydrology is always willing to consider collaborative opportunities for research and/or its adoption. I'll be happy to discuss possibilities at any time.

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CRC PUBLICATIONS LIST

Reports, videos and software, available from the CRC, are listed in our Publications List.

Copies of the Publications List are available on request from the Centre Office on 03 9905 2704 or can be downloaded from the CRC website at

www.catchment.crc.org.au

All prices listed include GST, postage and handling.

All of the Centre's products can be ordered through the Centre Office.

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PROGRAM 1

PREDICTING CATCHMENT BEHAVIOUR

Program Leader
ROB VERTESSY

Report by Rob Vertessy

Project 1.1: Development of a Catchment Modelling Toolkit

Background

By necessity, the 'ramp-up' phase in any CRC project tends to be sluggish. It seems to take forever to get the right staff and students in place, and it is a non-trivial task to make the inter-agency linkages work smoothly. There are enormous transaction costs in getting people to understand one another and accept one another's ideas. Finally, when a well-drilled team is formed it invariably enters into crisis mode once it confronts the enormity of the promises that the project leader has made! Luckily these crises gradually fade away and productivity starts. Like most of the other programs in the CRC, the Predicting Catchment Behaviour program has entered its 'all hands on deck' phase. Below is a pen-picture of some of the activity going on in our program, focussing on Project 1.1: Development of a Catchment Modelling Toolkit).

Survey on catchment modelling in Australia

The Project 1.1 team has completed an extensive scene-setting exercise. This has involved running surveys targeted at managers, model users and model developers. The survey results provide great insight into the state of catchment modelling in Australia and the picture is pretty dismal. There is widespread evidence of duplication of effort in model building and high levels of dissatisfaction with the state of models (with respect to their transparency, availability, ease of use and documentation). There is large gulf between those who write models and those who need to apply them in practice. Across the industry, we sense a great deal of support (though a fair measure of scepticism too!) for the notion of a new catchment modelling toolkit; a unified system of software that would permit users to build and apply hydrologic models with much greater ease than is possible today.

Comparison of software shells

Six alternative software architectures (think of these as 'shells') that could serve as the basis for such a toolkit are being compared by the project team. Two of these (Tarsier and ICMS) are under active development in our CRC. The other four are being developed by research teams in the United States and the Netherlands, and we are setting up research collaboration with these groups now so that we can properly evaluate their systems. To kick this off we will be running a joint workshop in the eastern United States, possibly as early as May this year. By the end of the year we will have chosen one of these frameworks (or parts of more than one) to form the basis of the toolkit. Next year we will work with other projects in the CRC (and with external collaborators) to test-bed the chosen framework with their models. If we succeed in this task then the way is clear over the following three years to populate the framework with models and disseminate them to users via training workshops and a web portal. A major thread in such future work would be model integration, aimed at delivering the multi-objective analysis tools that everyone wants but can't get at present.

Toolkit preparation

So, what's keeping us so busy? Well, the transaction costs I mentioned above have been great. We have a big team feeding diverse and rich ideas that have to be checked out systematically. There's been a lot of literature reviewing and web crawling, culminating in the documentation of ideas so that the team can effectively debate different options. But we can't keep those ideas to ourselves. Understandably, there is growing pressure from outside to articulate what the toolkit team are on about, and progressively we are rising to the challenge of telling people. Thus far, it's been awkward describing what we are proposing because we are still learning ourselves. However, the pieces are falling into place so you can all expect to hear much more from us this year.

The toolkit will be in the spotlight at the forthcoming CRC meeting at Cobram in April; this is a great opportunity for us to communicate our ideas to you and for you to shape the direction that the toolkit takes. Rob Argent and Susan Cuddy are running a special session at the MODSIM2001 Conference in December this year; this will attract some of the top people in model development and will thus be a great forum for testing our ideas.

Collaboration with researchers/stakeholders

Meanwhile, our software engineers (Joel Rahman, Shane Seaton, Fred Watson and John Coleman) are busy extending the capabilities of Tarsier and ICMS and working with various project teams to evaluate these frameworks on real modelling problems. Joel, Shane and Fred are using Tarsier as the basis for an Environmental Management Support System (EMSS) for the South East Queensland Regional Water Quality Management Strategy.

We've been working with stakeholders for some months to ascertain their needs to present them with our first prototype of the EMSS at a workshop in Brisbane in mid March. Francis Chiew and Phil Scanlon play a vital role in this work by providing model algorithms and calibration, and data appraisal. Delivery of the final EMSS is expected in August 2001, so we are running on a very tight schedule. John Coleman and Susan Cuddy have entered

the home stretch with the ICMS development, preparing tutorials and documentation that will be needed for a series of training workshops to be run in the second half of this year.

Collaborators at ICAM, ANU (Tony Jakeman, Barry Croke and their students) are providing hydrologic and economic models (focussed mainly on the Namoi and Murrumbidgee catchments) to sit within ICMS. This relationship is a good example of how we'd like to see the toolkit development proceed in the future; satellite groups focussing their modelling effort via a central software system that others can then benefit from.

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PROGRAM 2

LAND-USE IMPACTS ON RIVERS

Program Leader
PETER HAIRSINE

Report by Jon Olley

Project 2.14: Improved Methods for Targeting River Restoration Works

Keys to successful river rehabilitation

Large amounts of money are being spent on river rehabilitation, in spite of the current inability to predict with reasonable certainty the long term physical and ecological outcomes of remedial work.

The success or otherwise of river rehabilitation works depends upon the catchment-scale controls of the flow regime and the sediment regime. In many rivers the flow and sediment regimes have changed greatly since European settlement, with profound impacts on channel form and instream physical habitat. River rehabilitation undertaken without an understanding of the status and history of the flow and sediment regime is unlikely to be successful.

Present methods

The current approaches to river rehabilitation rely on the creation of appropriate physical habitat. To maximise the potential for success, the long term viability of habitat creation needs to be assessed in the context of the current flow and sediment regimes. Successful river rehabilitation needs to harness a river's own capacity to create and maintain appropriate physical habitat, rather than work against the river. Rivers are dynamic systems and physical disturbance of instream habitat is both natural and necessary to maintain healthy and diverse aquatic populations. Understanding the natural and modified disturbance regimes – extreme events of flow and sediment transport – are necessary precursors to successful river rehabilitation.

Classifying river habitats

A range of river habitat classifications are available for use by river managers. In most classifications, however, the link between catchment conditions, river processes and habitat is absent or poorly developed. A two-year CRC for Catchment Hydrology Associated Project run by CSIRO Land and Water, and funded by AFFA under the Fish Rehab Program (a part of MDB-2001) is attempting to develop a river habitat classification based on hillslope and river processes. The aim is to link these processes with the occurrence of habitat, at a variety of scales, and to gauge the effects of land use on riverine habitats. If successful, the new classification scheme will allow managers to estimate the 'pristine' (pre-settlement) reference condition of any reach of a river, and thus

THE THIRD AUSTRALIAN STREAM MANAGEMENT CONFERENCE - THE VALUE OF HEALTHY STREAMS

27-29 August 2001

Hilton Hotel
Elizabeth Street
Brisbane

The Third Australian Stream Management Conference will be held during 27 - 29 August 2001 in conjunction with the 2001 River Symposium (29-31 August) and associated with the Third Australian Fishways Technical Workshop (30-31 August).

In support of the 'Value of Healthy Streams' theme, the Conference is centred on four key areas:

- Ecosystem services
- Hydrological connectivity
- Bio-physical integration
- Tools and techniques

DETAILS OF CONFERENCE ACCOMMODATION AND COSTS NOW ON-LINE at www.catchment.crc.org.au/streamconference

Book your accommodation early to ensure a room - please quote the conference name when booking.

WATER ALLOCATION AND TRADING VIDEO

IRRIGATORS' ATTITUDES TO WATER ALLOCATION AND TRADING IN THE GOULBURN-MURRAY CATCHMENT

Dr John Tisdell
Program Leader - Water Allocation
CRC for Catchment Hydrology
Griffith University

November 2000

CRC Video 00/6

This presentation describes the results and findings of a survey of irrigators' attitudes to COAG reforms: temporary and permanent water trading; the role of the water authority in the market; and the environmental impact of trade. The survey also elicited irrigators' attitudes to breaking the nexus between land and water, points of blockage in current water markets and possible adjustments to trading rules and procedures.

COPIES ARE AVAILABLE FOR $27.50 (INC GST, POSTAGE AND HANDLING) THROUGH THE CENTRE OFFICE.

Contact Virginia Verrelli on 03 9905 2704 or by email virginia.verrelli@eng.monash.edu.au

evaluate the extent of habitat alteration. It will also enable assessment of the effects of changes in catchment management on riverine habitat. Managers using the new scheme will be able to determine the consequence of varying the flow regime and/or sediment supply on the habitat condition in a section of river.

Predicting river habitats

River habitat will be predicted at two scales: river reach (5-100 km) and within-channel (1-10m). At the river reach scale, the occurrence of seven channel types will be predicted based on estimates of sediment supply and sediment transport capacity. These channel types are: bedrock, boulder pool-riffle, cobble pool-riffle, gravel pool-riffle, gravel meandering, sand meandering and sand sheet. The 'sand sheet' class denotes channels that have been smothered by sand slugs resulting from catchment erosion. For within-channel habitats, the goal is to predict total habitat diversity, the complexity of bed sediment and flow velocity, and the density of woody debris, open areas and aquatic vegetation (both epibenthic algae and aquatic macrophytes) occurring within channels. Channel type, some measures of flow regime, and possibly bank vegetation will be used to predict within-channel habitat.

Data for project

The project is using data from maps, aerial photos, satellite imagery, together with data obtained from an extensive fieldwork program. Up to 36 study sites across the upper Murrumbidgee catchment are being assessed in the field for their channel type, and 10-25 sites for within-channel habitat studies. At present, most of the channel-type field sites have been visited and surveyed. The channel habitat fieldwork will begin next spring. The assessments of sediment supply and sediment transport capacity are being made using the methods CSIRO Land and Water has developed for use in the NLWRA. These involve modelling of hillslope and gully erosion and stream transport based on DEM analyses and hydrologic regionalisations.

Project team

The project is led by Bill Young, but Ralph Ogden is doing all the hard work. Ian Prosser is leading the spatial modelling components, assisted by Andrew Hughes, and Jon Olley will provide OSL dates to help understand the origins of sand slugs in the catchment. Ralph has been ably assisted in the field by students Daniel Wilkins and Amanda Windeyer, and by Danny Hunt, Noel Oliver, Carolyn Young, Alison Skinner and Anthony Scott.

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PROGRAM 3

SUSTAINABLE WATER ALLOCATION

Program Leader
JOHN TISDELL

Report by John Tisdell

The Impact of the CAP in the Goulburn Broken Catchment

A cap on water entitlements in the Murray-Darling Basin ('the CAP') was introduced in June 1995 as part of a strategy to overcome water shortages. The CAP effectively reduced water allocations throughout the catchment. As part of the first phase of CRC Project 3.2: "Enhancement of the water market reform process: A socio economic analysis of guidelines and procedures for trading in mature water markets", irrigators and community members were asked whether they had perceived an impact on their farm or business enterprise. Table 1 presents a summary of the results. 26.8% and 5.9% of irrigators and community members, respectively, stated that the CAP had had an impact on their farm enterprise or business.

The highest perceived impact of the CAP by irrigators is in the Murray valley areas with 34.3% of irrigators having perceived an impact . In contrast, all irrigator respondents from the Goulburn River (16) and 83.9% and 56.3% of irrigators responding from the Torrumbarry and Shepparton areas respectively stated that the CAP had not had an impact on them.

Table 1. Impact of the CAP on farm enterprises

	Irrigator Farm enterprises		Community Businesses	
	Frequency	**Percent**	**Frequency**	**Percent**
Yes	69	26.8	11	5.9
No	188	73.2	175	94.1
Total	257	100.0	186	100.0

Comments by irrigators

The main comments by irrigator respondents concerning the impact of the CAP on their enterprise are listed in *Table 2*. According to the respondents, the CAP has forced the recognition of water as a scarce resource and more efficient use of it, decreasing production and creating uncertainty for future planning regarding the costs and availability of water.

Table 2. Impacts of the CAP on irrigators in the Goulburn Broken catchment - Main comments by irrigators

- CAP knowledge
  - Did not know there is a CAP (2)

- Water availability, usage and security
  - There are higher levels of water uptake and usage (1)
  - There is not enough water available (4), in particular for Russell Burbank potatoes (2)
  - There is less water available (14)
  - Particularly from underground sources (3)
  - Fewer options for water storage (3)
  - A decreased sales allocation (3)
  - Less water available in the off season (2)
  - Entitlements have increased security (2)

- Market impact
  - Difficult to get extra water entitlements (1)
  - Need to use trading to secure water entitlements (1)
  - Entitlements being purchased outside the traditional use area (1)
  - Water is more expensive (5) and more valuable (2)
  - Selling water is more valuable than growing crops (1)
  - Temporary transfers have increased profitability (1)
  - Inspired over purchase (2) and more development (1) to establish security

- Concern over costs and restrictions on bores
  - Concern over the costs and restrictions of bore licences (2)

- Forced recognition of water as a scarce resource and more efficient use of it.
  - Forcing the recognition of water as a scarce resource and more efficient use of it (10),
  - Incorporating water availability into future planning (3)
  - Monitoring of use (1)
  - Forcing unsustainable practices (1)

- Decreased production
  - Has increased costs of production (5) including admin costs (1)
  - Decreasing production (10)
  - Causing financial hardships/ threatening future viability (3)
  - Ceasing production (2)
  - Changing the mix of production (1)
  - Changing patterns of seasonal water use to those inappropriate for crops (1)

- Limited future development
  - Has created uncertainty for future planning regarding the costs and availability of water (6)

- Social perceptions
  - A social perception of a resource being taken away (1)

SALINITY DISPOSAL BASIN REPORTS NOW AVAILABLE ON-LINE

The CRC Project S2, 'On-Farm and Community Scale Salt Disposal Basins on the Riverine Plain, was a collaborative project between the CRC for Catchment Hydrology, CSIRO Land and Water and the Murray-Darling Basin Commission.

The outputs of the project include fifteen technical reports covering key issues in the siting, design and management of salt disposal basins.

Reports in this series can be downloaded (free) as pdf files from the CRC website at the address - www.catchment.crc.org.au/disposalbasins

The reports are also available in printed form for $27.50 (inc. GST) from the CRC Centre Office

SHOWCASING CRC POSTGRADUATE RESEARCH

'THE CONTRIBUTION OF THE SOCIAL SCIENCES TO ENVIRONMENTAL DECISION MAKING'

10.00am - 3.30pm
Friday 6 April 2001

Griffith University Ecocentre
Griffith University, Nathan Campus

Lunch and break refreshments supplied

Seven CRC postgraduate students will deliver 40 minute presentations to support the seminar day's theme.

The presenters are all PhD scholars in the Citizen Science Research Group of the Cooperative Research Centres (CRC) for Catchment Hydrology and Coastal, Estuary and Waterways Management in the Australian School of Environmental Studies at Griffith University.

RSVP (for catering purposes) by Wed 4th April 2001 to Kate Williamson
tel: (07) 3875 7989 or email: K.Williamson@mailbox.gu.edu.au

For further information , please contact
Dr John Fien on (07) 3875 7105.

Details of the program are available at www.catchment.crc.org.au/events

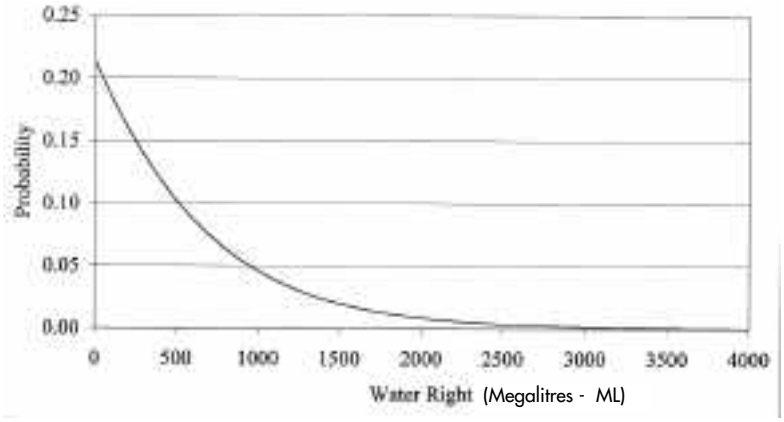

Figure 1. Probability of CAP impact by size of water allocation

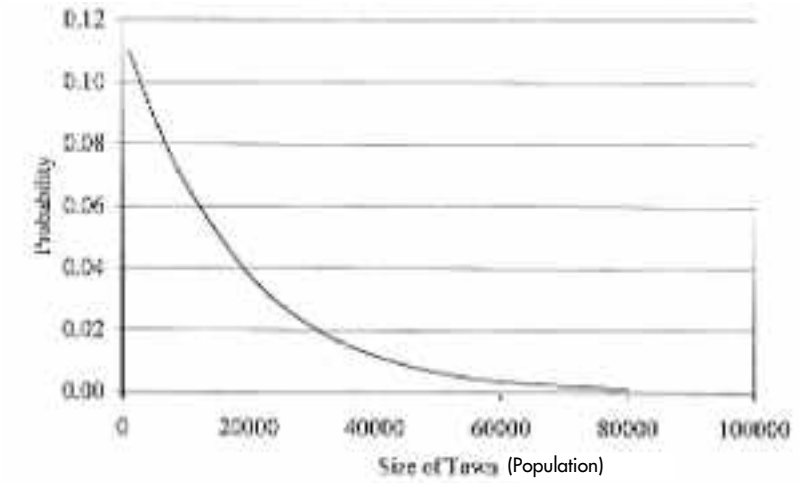

Figure 2. Probability of CAP impact by size of town

The perceived impact of the CAP on individual irrigators and community members depends on the size of their water right and the town they live in, respectively.

Likelihood of CAP impacts

Figures 1 and 2 present the probability functions for the likelihood of perceiving a CAP impact. As the size of an irrigator's water allocation increases, the likelihood of perceiving an impact from the CAP decreases from over 20% by those irrigators with water rights less than 60ML, to less than 5% for irrigators with water rights over 950ML. Over 1000ML the probability of an irrigator perceiving a CAP impact on their farm enterprise is negligible.

According to Community responses, smaller towns with populations of less than 1000 have been most impacted by the CAP. The perceived impact of the CAP on town businesses reduces significantly as the town population increases from 1,000 to 30,000. The probability of a community member perceiving a CAP impact on town businesses falls from over 10% in small towns to less than 2% in town with populations of 31,000.

Conclusion

This work is the first of its kind exploring the impact of the cap on water users in the Goulburn-Broken catchment. The findings are important in evaluating the extent and distribution of the impact of the CAP in our CRC focus catchments.

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PROGRAM 4

URBAN STORMWATER QUALITY

Program Leader
TONY WONG

Report by Tony Wong

A Decision Support System for Ecologically-based Urban Stormwater Management

Background

In recent years, initiatives to protect the aquatic environment of urban areas have been a focus of many federal, state and local government organisations and community groups. Many of these initiatives have successfully reduced point sources such as sewage discharge and industrial effluent. Now urban stormwater and its role in conveying pollutants to our streams is widely recognised as the next major issue to tackle. However, the sources of urban pollutants are diffuse and inherently more difficult to manage.

Successful approaches require catchment-wide integration of urban drainage infrastructure planning and design, with elements of urban hydrology, ecologically sustainable land development, landuse planning, urban landscape architecture and asset life-cycle economics. The CRC's Urban Stormwater Quality Research Program aims to develop a Decision Support System (DSS) for the design of sustainable urban storm drainage systems. The DSS is centred around the utilisation of a range of stormwater treatment measures to achieve desired water quality and flow management standards for the protection of aquatic ecosystem health. The DSS will also provide a quantitative basis for predicting the performance of stormwater management measures and define their optimal design standards.

The research team has now completed the first stage of the development program and will be field testing the Pilot DSS with officers in Brisbane City Council and Melbourne Water over the next nine months. A series of training workshops on the operation of the Pilot DSS will commence in April 2001.

Key Features of the Pilot DSS

The Pilot DSS is based on an extensive literature review and the existing knowledge of the CRC researchers. The Pilot DSS has already incorporated most of the key modelling features and architecture of the DSS. Research activities undertaken by the CRC will be directed at improving the scientific rigour of the modules in the DSS used in modelling the various water quality improvement processes involved in the use of gross pollutant traps, buffer strips, grass swales, infiltration systems, constructed wetlands and ponds as depicted in *Figure 3*.

The DSS will simulate the performance of stormwater management measures on an event or continuous basis using historical and/or stochastically generated data. It will have the capability to operate at a range of location and time scales, suitable for catchment areas from 1 ha to 100 km^2.

Figures 4 and *5* show a typical output of the Pilot DSS presenting a time series of flow and cumulative probability plot of TSS concentrations predicted at the inflow and outflow of a constructed wetland. Outflow characteristics from a stormwater quality improvement facility or from a "treatment train" can be represented in a number of ways including the use of cumulative probability plots. These approaches support a risk-based approach to the management of stormwater quality in receiving waters.

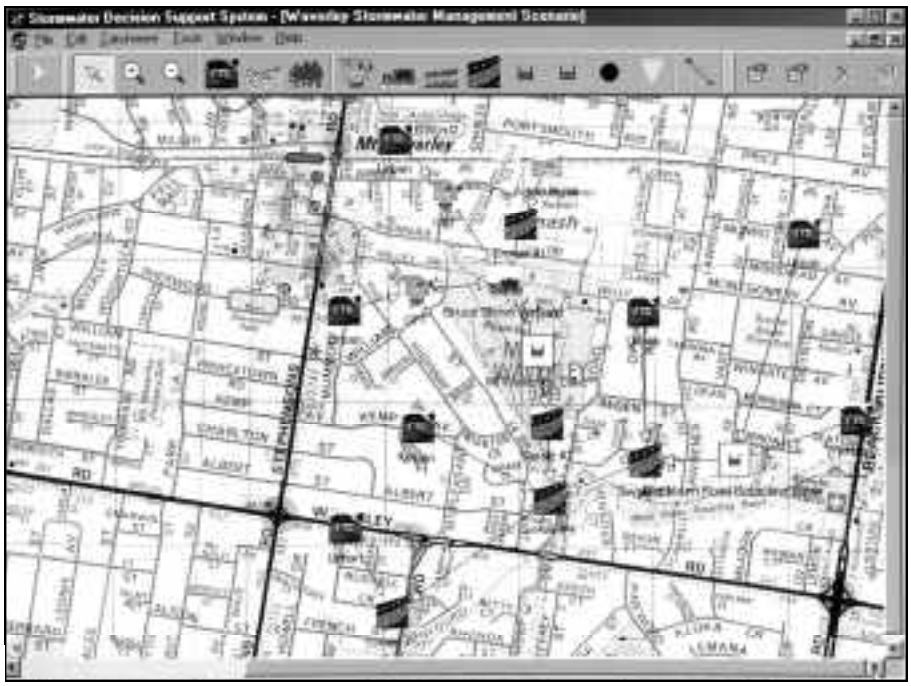

Figure 3

URBAN STORMWATER QUALITY DECISION SUPPORT SYSTEM PROTOTYPE

One of the first key research outcomes to be delivered to our industry Parties for trialling is Program 4's Urban Stormwater Decision Support System (DSS).

A beta version of the DSS has been delivered to Melbourne Water and Brisbane City Council this month and training workshops are planned for April. In keeping with the Communication and Adoption Plan for the DSS, it will be field tested in these two organisations over the next 12 months as part of its development before a wider release.

For further information, please contact Tony Wong by email: tony.wong@eng.monash.edu.au.

WATER SENSITIVE URBAN DESIGN

WATER SENSITIVE ROAD DESIGN - DESIGN OPTIONS FOR IMPROVING STORMWATER QUALITY OF ROAD RUNOFF

by

Tony Wong
Peter Breen
Sara Lloyd

Report 00/1

This joint publication with the CRC for Freshwater Ecology investigates opportunities for incorporating stormwater quality improvement measures into road design practices for protecting aquatic ecosystems.

Copies of the report are available from the Centre Office for $27.50 (includes postage and GST).

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

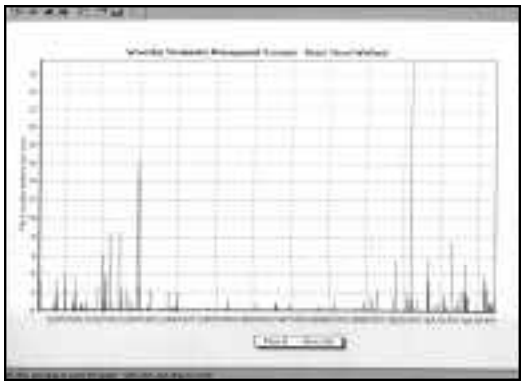

Fig 4

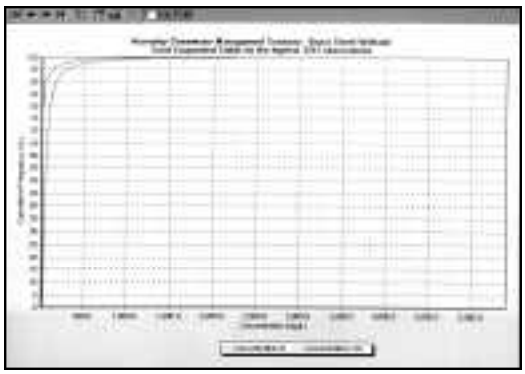

Fig 5

The Universal Stormwater Treatment Model

The mechanisms promoted in the removal of stormwater pollutants encompass physical, chemical and biological processes. Owing to the intermittent nature of stormwater inflow, physical processes associated with detention for sedimentation and filtration (either through vegetated systems or through an infiltration medium) are the principal mechanisms by which stormwater contaminants are first intercepted. Subsequent chemical and biological processes can influence the transformation of these contaminants during the inter-event period. The Pilot DSS has placed particular emphasis on modelling the physical processes during storm events in the first instance.

In the DSS the various stormwater treatment measures by which contaminants are first intercepted and detained are being described with a unified model, the Universal Stormwater Treatment Model (USTM). Grass swales, wetlands, ponds and infiltration systems are considered to be a single continuum of treatment based around flow attenuation and detention, and particle sedimentation and filtration. Grass swales are simply ephemeral vegetated systems (such as strips of lawn) operating at a higher hydraulic loading than constructed wetlands. Constructed wetlands are generally shallow densely vegetated systems compared to ponds which typically have deeper open water and fringing vegetation. Hydraulic loading, vegetation density and areal coverage, hydraulic efficiency and the characteristics of the target pollutants (eg. particle size distribution and contaminant speciation) largely influence their differences in performance. Similarly, infiltration systems are typically vertical filtration systems - compared to the horizontal filtration systems of grass swales and wetlands. Those infiltration systems rely on enhanced sedimentation and surface adhesion (promoted by biofilm growth) for removal of fine particles.

Validity of concepts for unified model

The validity of this unified conceptual approach to simulating the operation of stormwater treatment measures can be demonstrated by empirical analysis of observed water quality (predominantly TSS) improvements in swales, wetlands, ponds and infiltration basins during storm events and also by fitting observed storm events water quality data from these treatment systems to a universal stormwater treatment model. While it is acknowledged that there are many complex and interacting biological and chemical processes affecting water quality in aquatic systems, the USTM is considered to provide an efficient mechanism by which urban catchment and waterway managers can predict and assess the performance of stormwater treatment measures in a Decision Support System.

Future research and enhancements to the model will include modelling the biological and chemical processes considered dominant in the various stormwater quality improvement facilities during the inter-event periods.

Summary

The Pilot DSS being tested over the next nine months is a first step towards the CRC's Urban Stormwater Quality Program providing urban waterway managers with a decision support tool to:

a) determine the likely water quality emanating from specific catchments

b) predict the performance of specific stormwater treatment measures in protecting receiving water quality

c) design an integrated stormwater management plan for a catchment, and

d) evaluate the success of specific treatment measures, or an entire catchment plan, against a range of water quality standards.

We anticipate the the DSS will evolve as outputs from CRC research projects (and other organisations) become available.

Over the next five years, the CRC, in conjunction with industry practitioners, will regularly evaluate the performance of the DSS, and target research activities to address knowledge gaps identified in individual models.

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PROGRAM 5
CLIMATE VARIABILITY

Program Leader
TOM McMAHON

Report by Sri Srikanthan and Tom McMahon

Project 5.2: National data bank of stochastic climate and streamflow models

Long wet and dry periods

One major issue from the last Project Review Panel meeting for Project 5.2 held in June 2000 was the presence of long wet and dry periods in some rainfall records. This was examined as part of the generation of annual rainfall data.

Long rainfall records (of the order of 140 years or more) are needed to detect these long periods of wet and dry spells. Forty rainfall stations with long records were selected to model the annual rainfall data. The locations of the rainfall sites are shown in Figure 6.

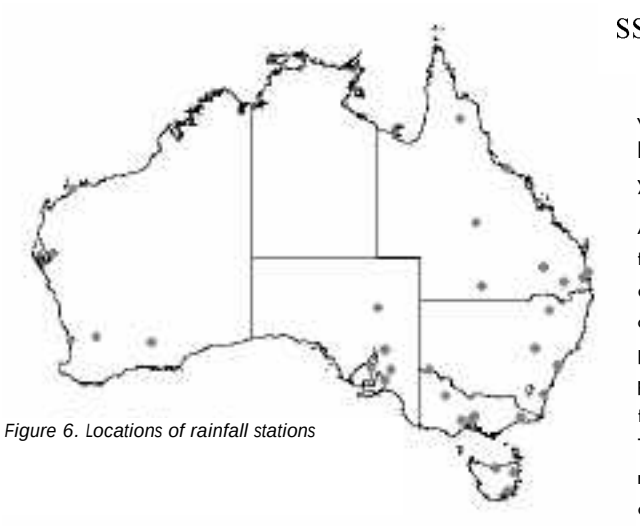

Figure 6. Locations of rainfall stations

Persistence of wet and dry states

The Hidden State Markov (HSM) model, developed by Mark Thyer and George Kuczera (University of Newcastle), was applied to the annual rainfall data from these 40 rainfall stations.

One of the issues raised was that the degree of the persistence in the wet and dry states depends on the starting month of the water year. Because of this, the calibration of the HSM model was achieved by running the HSM model 12 times and starting each calibration with starting months from January through to December. The separation of the wet and dry state parameter can be assessed by using the Wet and Dry Separation Index (WADSI). This is defined as:

$$\text{WADSI} = \frac{\mu_W - \mu_D}{\sqrt{\left(\sigma_W^2 + \sigma_D^2\right)}}$$

where μ_W, μ_D represent the mean of the wet and dry state distributions respectively,

and σ_W, σ_D – the standard deviation of the wet and dry state distributions respectively.

Based on this, the stations can be divided into two groups. The stations with significant differences in the means are able to be assigned to one group and the remaining sites belong to the other group.

Indicating or defining persistence

The persistence of the rainfall to remain in either the set or dry state can be assessed by using the State Signal Indicator (SSI), which is defined as:

$$\text{SSI} = \frac{\sum \left| P(W) - 0.5 \right|}{N}$$

where P(W) is the probability of a year being in a wet state and N the number of years of data.

A value of 0.3 or higher for SSI indicates the presence of persistence in the wet and/or dry states. Here again, the stations can be classified into two groups: one with persistence and the others without persistence. Work is under way to relate the two groups to geography climate type. This will enable one to choose the right model for generated annual data based on the presence or absence of long periods of wet and dry spells in the observed data.

Stochastic hydrology workshop

In addition to the above work, a successful Workshop on "Stochastic Hydrology for Middle and Senior Managers" was held on 22 February 2001, at the University of Melbourne. Twenty two participants attended. Along with us, Bruce Rhodes (Melbourne Water) and Geoff Pegram (University of Natal, Republic of South Africa) gave presentations at the workshop.

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CLIMATE VARIABILITY PROGRAM TECHNICAL REPORT

STOCHASTIC GENERATION OF CLIMATE DATA: A REVIEW

by
Ratnasingham Srikanthan
Tom McMahon

Report 00/16

This report reviews the state of research and practice in the stochastic generation of annual, monthly and daily climate data.

Copies of the report are available from the Centre Office for $27.50 (includes postage and GST).

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

THE THIRD AUSTRALIAN STREAM MANAGEMENT CONFERENCE - THE VALUE OF HEALTHY STREAMS

27-29 August 2001

Hilton Hotel
Elizabeth Street
Brisbane

The Third Australian Stream Management Conference will be held during 27 - 29 August 2001 in conjunction with the 2001 RiverSymposium (29-31 August) and associated with the Third Australian Fishways Technical Workshop (30-31 August).

In support of the 'Value of Healthy Streams' theme, the Conference is centred on four key areas:

· Ecosystem services
· Hydrological connectivity
· Bio-physical integration
· Tools and techniques

PLANNING TO ATTEND, SUBMIT A PAPER OR A POSTER?

To register your interest in attending the conference or submitting an abstract, please send an email with all your contact details to stream.conference@dnr.qld.gov.au

More details are available at www.catchment.crc.org.au/streamconference

PROGRAM 6
RIVER RESTORATION

Program Leader
IAN RUTHERFURD

Report by Michael Stewardson and Chris Gippel

Project 6.7: Developing an Environmental Flow Methodology: A Trial on the Campaspe River

The natural flow paradigm

Throughout Australia we are in a process of refining the methods used to assess the environmental flow requirements of freshwater ecosystems. After numerous reviews, workshops, and studies conducted over the last fifteen years, a basic tool kit is now available. However, ongoing development of these methods is required to keep pace with increasing knowledge of the influence of flow on stream processes.

A major development in this field is the natural flow paradigm, which has been stated as

> "the full range of natural intra- and interannual variation of hydrological regimes, and associated characteristics of timing, duration, frequency and rate of change, are critical in sustaining the full native biodiversity and integrity of aquatic ecosystems" (Richter et al., 1997).

Some recent environmental flow studies adopt this natural flow paradigm by designing environmental flow regimes that mimic the natural variability in flows. However, there is no widely accepted method for identifying the key aspects of flow variability that should be protected.

The flow event method

In project 6.7 we are developing a method of incorporating variability into environmental flow regimes, called the flow events method. This method has the advantage that ecological benefits of the environmental flow are clearly articulated, and available process knowledge is included in the development of flow recommendations. The method also accounts for the natural dynamism in flow-related bio-physical processes by using the natural flow regime as a template for the environmental flow regime.

Modelling and survey methods

The flow events method is now fully developed and being applied to rivers in south east Victoria. Project 6.7 is now focussed on developing better modelling and survey methods for deriving relations between habitat conditions and flow. In particular, we are developing efficient and reliable protocols for carrying out channel surveys for environmental flow studies. Four CRC for Catchment Hydrology vacation students (Sam Bayley, Phil Birtles, Elisa Howes and Lauren Sheather) spent their summer collecting detailed survey information on five rivers throughout Victoria. These data will be used to evaluate a range of sampling protocols and identify improvements.

We are also making some progress in developing simple models for predicting the relationships between habitat conditions and discharge. Traditionally, these relationships are derived by fitting a curve to survey data collected at a range of discharges or using one-dimensional flow models. Both methods can be costly and subject to high level of uncertainty. A simpler approach is to survey conditions at one discharge and to use an empirical model to represent variations in conditions with flow. Preliminary results of this research are promising.

Report on flow events method

The flow events method has been documented in a CRC for Catchment Hydrology report, which is due for release soon. The improved survey and modelling techniques will be made available over the next two years of the project. Anybody wanting more information on this project should contact me at m.stewardson@civag.unimelb.edu.au.

Project 6.1: Developing Criteria and Concepts for Planning the Evaluation of Stream Rehabilitation Projects

Uncertainty in rehabilitation planning

The importance of explicitly stating the level of certainty associated with experimental results and model predictions is generally accepted amongst the scientific community. This is a relatively straightforward procedure in the ideal cases of well-controlled experiments and rigorous model testing. However, while few of the issues associated with river management lend themselves to simple experimentation, management demands immediate advice that is "scientifically defensible". The advice often has to be given on the basis of scant local information, supported by the experience of the scientific team in other rivers, and published literature on related topics. Even in ideal cases where time and resources are allocated to conduct a more thorough investigation, the recommendations are usually little more than hypotheses.

Sources of uncertainty

A sound rehabilitation plan should include an assessment of the associated uncertainties. Based on a review of a case study rehabilitation project, we have identified three major sources of uncertainty in stream rehabilitation planning:

- identifying the nature and cause of historic physical and biological changes to the stream
- predicting the response of the stream to proposed

rehabilitation measures

- selecting a rehabilitation target that reflects the shared goals of project stakeholders

It can be tempting to overlook uncertainties, particularly when some proposed rehabilitation measure has already gained widespread support. However, evaluating and addressing uncertainties through modelling, trials or other types of investigation is critical if we are to progress our knowledge base for stream rehabilitation in Australia.

A qualitative approach to evaluating uncertainty

It would rarely be possible to accurately quantify the level of uncertainty associated with the various aspects of rehabilitation planning. We have developed a qualitative approach to documenting uncertainty in river rehabilitation planning that uses descriptive scales of probability. The method is simple to apply using readily available information. It is simply a structured way of thinking through the possible sources of uncertainty and likely impacts on the benefits of rehabilitation options.

An explicit consideration of uncertainty will allow managers and the wider community to firstly critically examine their beliefs in the face of available scientific evidence, and secondly to make more informed decisions regarding the commitment of resources to rehabilitation measures.

Anybody wanting more information on this new method for documenting uncertainty for rehabilitation planning should contact Mike Stewardson at m.stewardson@civag.unimelb.edu.au

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COMMUNICATION AND ADOPTION PROGRAM

Program Leader
DAVID PERRY

The Flow on Effect – March 2001

Here are some short updates from the Communication and Adoption Program.

New Technical Report – Flood Estimation

A new CRC Technical Report entitled 'Monte Carlo Simulation of Flood Frequency Curves from Rainfall' by Ataur Rahman, Erwin Weinmann, Tam Hoang, Eric Laurenson and Rory Nathan (Technical Report 01/4) is now available from the Centre Office. The report describes work done in the initial CRC's Flood Hydrology Program.

Project FL1: 'A holistic approach to rainfall-based design flood estimation', aimed to reduce the bias and uncertainties in Australian design flood estimates by developing rainfall-based design flood estimation procedures which better take account of the interaction and joint probability of the different flood producing components, i.e. a holistic approach.

The work described in this new Techinical Report examines a range of joint probability approaches to allow for the interaction of different components. The results certainly seem very promising, and suggest that a shift in thinking on design floods is not far away.

Urban Stormwater Quality Decision Support System

One of the first major research outcomes to be delivered to our industry Parties for trialling is Program 4's Urban Stormwater Decision Support System (DSS). A beta version of the DSS has been delivered to Melbourne Water and Brisbane City Council this month and training workshops are planned for April. In keeping with the Communication and Adoption Plan for the DSS, it will be field tested in these two organisations over the next twelve months as part of its development before a wider release. For further information please read Tony Wong's article in this *Catchword* (Program 4).

CRC Communication Review – thank you

The CRC's Business Plan states that the CRC will engage independent consultants to review the effectiveness of our communication activities at the end of Years 1, 3 and 5. Through a competitive tender process the CRC engaged the Brisbane-based company Econnect Communications to undertake the review. As well as assessing the effectiveness of the CRC's current communications, the review will provide recommendations for improvements.

A number of *Catchword* readers would have received the survey distributed by Econnect. I would like to thank those people who completed and returned the questionnaire by

CRC PROJECT SHEETS

Printed versions of the CRC project sheets (two page documents describing the key elements of research projects in CRC Programs except River Restoration and Communication and Adoption) are now available from the Centre Office.

There are 14 project sheets in total, and each gives details of research objectives, expected outcomes, target problems, key tasks, links, staff involved and contacts for that CRC project. They are an excellent way to quickly familiarise yourself with the nature and extent of our research program.

Copies are available by contacting Virginia Verrelli at the Centre Office on 03 9905 2704 or email virginia.verrelli@eng.monash.edu.au.

These sheets are also available for downloading from our website.

Look under Research 1999-2006 and follow the links for 'detailed information'

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.

the due date. Details of the outcomes of the review and our responses to improve our communication will be available in future issues of *Catchword*.

Upcoming CRC events – where to get details

Last month Tom McMahon and other researchers involved in the Climate Variability Program ran a 'Stochastic Hydrology Workshop for Middle and Senior Managers' in Melbourne. According to responses from participants, almost half of them found out about the workshop through email.

If you would like to learn about upcoming CRC events as soon as they become available then subscribe to our events notification list at:
www.catchment.crc.org.au/subscribe or contact Virginia at the Centre Office:

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Report by Pat Feehan

The focus catchment approach - reality bites

We have now been working on CRC for Catchment Hydrology issues within the Goulburn Broken catchment for about 18 months. How has the focus catchment approach worked to date?

The CRC's Mission is to deliver to resource managers the capability to assess the hydrologic impact of land use and water management decisions at whole-of-catchment scale. One of the CRC's key performance indicators is the adoption of research results by industry. The focus catchment approach is one way of working closely with relevant partners to achieve this.

At Goulburn-Murray Water (G-MW) we have also taken the approach that we wanted to ensure that research results are translated into "on-the-ground" responses. We are making a major investment in the research and we want to make sure that research outcomes are used, and used quickly.

Our approach has been to appoint key contacts for each project. Each key contact is a person who, as part of their normal work activities, would be likely to have some influence or responsibility to implement project research outcomes. Our thinking is to force the issue by ensuring key implementors are closely aligned with relevant projects. Not all these key contacts are from within G-MW. For some projects, Catchment Management Authority staff are more appropriate contacts.

This approach also ensures that a range of people are exposed to CRC projects, and most importantly, it spares the Focus Catchment Coordinator from having to be totally across lots of projects.

This approach is working in some projects, and seems to be working best where there has been a fair bit of action in individual projects.

The focus catchment approach has other benefits. For example, it has drawn us into a wider research network. It has also drawn us into related, or associated, projects and has also allowed us to promote the CRC Communication and Adoption Planning approach in some of these other forums/projects.

It is probably too early to say if the focus catchment approach is successful, given that many projects are just hitting the ground, but it does seem to be moving in the right direction.

From a Focus Catchment Coordinator's perspective the approach means (besides a fair bit of work):

- Chasing colleagues for information and input to communication and adoption plans
- Being closer to researchers and research projects and being able to see interesting linkages or applications
- Exposure to a number of broader, or wider, fields
- Being harassed occasionally by David Perry
- Sharing ideas with other FCCs and seeing what goes on in other catchments.

My personal view is that the focus catchment approach is sound, it takes effort to make it work, but the potential benefits far outweigh the disadvantages.

Ask me what I think in a couple of years!

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POSTGRADUATES AND THEIR PROJECTS

Our postgraduate for March is:

Avijeet Ramchurn

I graduated from Monash University with a Bachelor's degree in Civil Engineering in 1997 and went home to Mauritius (which, for the uninitiated, is a small tropical island in the middle of the Indian Ocean) where I joined an engineering consultancy firm named Mega Design Co. Ltd.

As a graduate engineer, I was mostly involved at the design stage of a number of water and public health engineering projects, e.g water supply schemes, irrigation pipelines, sewerage schemes. I also had the luck to assist in the supervision of the rehabilitation works of a major water treatment plant.

After two years at work, I felt the desire to get back to university to do some research. My interests had always lain within the hydrology and water resources area, and in my mind there was only one place I could come to: Where else but Monash, where I had spent four fantastic years, and where I could count on links with the real world via the CRC for Catchment Hydrology! And when I eventually get back to Mauritius, I am sure that the skills in water resources management acquired here will be an invaluable asset to the country.

Actually, when I started Civil Engineering, my idea was to be a structural engineer. I had this fascination about building construction. As I went through my studies, my first real interest in water issues arose with a presentation I made on stormwater in second year. Third year Hydrology became a blast and the rest as they say, is history…

It's probably relevant to mention here that my interest in water issues was vastly encouraged by fact that Mauritius is a country with acute water problems, and I probably saw a future there.

Throughout the wet season, running water is available for a few hours in the morning and for a few hours in the afternoon to evening. With the use of a balancing water tank (an absolute necessity if you want water the whole day), the demand is more or less amply satisfied.

During the dry season, (ie summer), if cyclones do not bring rain, the water cuts are so severe that several regions of the island may go without running water for very long periods and depend solely on water delivery by cistern trucks. The hours of running water are reduced to about three hours per day and pressure falls so low that the water tanks (usually situated on the roof) do not get filled!

During the 1998 dry season, I had to keep filling buckets of water from the lowest tap on our property and carry it upstairs to pour the contents into the water reservoir…excellent exercise! Still we were glad when the pump started doing the job for us…

That fateful 1998 season resulted in the cessation of any political dilly-dallying on the construction of a major 25000 ML reservoir. Also, a number of water engineering projects already underway got closer scrutiny from the authorities and were thus accelerated.

So here I am, currently involved in Project 3.1: Integration of Water Balance, Climatic and Economic Models. My research topic, for an M.Eng.Sc, seemingly still under constant redefinition, is basically about the modelling of irrigator decisions of cropping areas, how they depend on seasonal forecasts and how they are influenced by the availability of on-farm storage. My project supervisor is Erwin Weinmann while my associate supervisor is Gary Codner.

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CRC POSTGRADUATE SCHOLARSHIPS

The Cooperative Research Centre (CRC) for Catchment Hydrology has funding for postgraduate scholarships at Masters and PhD level with Griffith University, Monash University and The University of Melbourne.

Full scholarships and top-up scholarships are available.

For initial details and application forms, please contact
Virginia Verrelli on
tel: (03) 9905 2704
fax: (03) 9905 5033
email:
virginia.verrelli@eng.monash.edu.au

Please note positions are open to Australian or New Zealand citizens or Permanent Residents of Australia only.

WANT TO KNOW WHAT'S GOING ON?

The CRC event calendar at www.catchment.crc.org.au allows you a 'sneak preview' of what is coming up month by month.

Details of CRC events (workshops, seminars, field tours etc.) are posted on the site as soon as they become available.

LOOK UNDER 'EVENTS' ON OUR WEBSITE.

CRC PROFILE

Report by Stuart Bunn

I became interested in the study of streams and rivers shortly after my undergraduate degree, while working as a field assistant on rehabilitated bauxite mine sites in southwestern Australia – a place where streams and rivers are few (especially non-saline ones) and, at the time, stream ecologists were fewer. I completed my PhD in 1985 at the University of Western Australia on the ecology of small forest streams, and worked briefly on the development of a biomonitoring program for the (then) Water Authority of Western Australia. Although I have maintained an active interest in the application of biomonitoring techniques, my research interests then (and now) have been largely focused on aquatic ecosystem processes with a particular emphasis on the linkages between aquatic systems and their catchments.

I left Perth in 1986 to take up a postdoctoral position at the University of Waterloo, Canada with Professor Noel Hynes – the 'grandfather' of stream ecology. During this time I had the opportunity to work on a range of aquatic systems, including the deciduous forest streams I had read so much about as well as tundra streams and lakes – all, of course, were vastly different from the small streams I had previously studied. I also had the good fortune of being able to spend many sessions with Noel Hynes, who was always willing to share his experiences and wisdom.

In 1988, I returned to Australia to take up a teaching position at Griffith University in Brisbane. I soon started working on several small projects across a range of aquatic systems, including local rainforest streams, coastal mangroves and River Murray billabongs – all with the common theme of identifying the major sources of organic carbon that support the aquatic food webs. In 1992, I was able to devote most of my time to research and took on the responsibility of coordinating the ecological component of the National Riparian Lands Program, funded by Land and Water Australia. This commissioned research program was developed in collaboration with the CRC for Catchment Hydrology, management agencies, and local community groups, at a series of catchment sites across Australia. It provided a fantastic opportunity to work on a series of specific research questions across a wide range of biomes.

My interests in catchment hydrology and river hydraulics began with the early realisation that these are major drivers of the structure and dynamics of stream and river ecosystems. After taking part in a few workshops with Bob Newbury and after five years of collaborative work with the two Ians (Prosser and Rutherfurd) from the CRC, I have learned enough to be dangerous and readily acknowledge there is much more to know. One of the great things about being involved in the CRC for Catchment Hydrology is the opportunity to continue working with scientists with these skills (and the tact and diplomacy to tell me to stick to the ecology!). Major river management issues, such as the determination of environmental flows, will never be resolved unless we can develop active and successful collaborations across these disciplines.

My current work in the CRC is focussed on two aspects of riparian land management and builds on work commenced in Phase One of the National Riparian Lands Program.

The first is on capacity of riparian zones to intercept and transform diffuse inputs of nitrogen from agricultural catchments (Project 2.5: Nitrogen and carbon dynamics in riparian buffer zones). This stems from the realisation that nitrogen is a major limiting nutrient for some stream systems (including ones we have worked on in southeast Queensland) as well as coastal ecosystems like Moreton Bay. While we are starting to get a better understanding of nutrient cycling in-stream, processes such as denitrification in riparian zones still remain a major unknown in Australian catchment settings.

The second (Project 6.4: Evaluation of riparian revegetation in a southeast Queensland catchment) centres on the assessment of the success (or otherwise) of riparian rehabilitation projects. This work is linked with other research and monitoring projects underway within the CRC for Freshwater Ecology and forms part of our joint CRC involvement in the Southeast Queensland Regional Water Quality Management Strategy.

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WHERE ARE THEY NOW?

Report by Christoph Zierholz

Not far away at all. I managed to relocate myself a measly 20 km, just across the ACT border into Queanbeyan. Shouldn't complain though as I wasn't looking for exotic places to work (not that Queanbeyan isn't exotic...) and have ended up with what I think is a very good job with the Centre for Natural Resources (DLWC). The local office is great with a good mix of people from different branches of the organisation so there is always new stuff to learn. The Centre for Natural Resources group has also gone from strength to strength from an initial two (Peter Fogarty and myself) to seven, with recent support from Queensland (aka Mark Littleboy).

Whilst with the CRC for Catchment Hydrology, I was working doing a masters on runoff and erosion processes following the January 1994 Sydney bushfires with my supervisors Peter Hairsine and Richard Greene and a tremendous amount of help from Neville Carrigy and Jim Brophy. As it occasionally happens in postgraduate research, we struck some unforeseen obstacles and the project was somewhat halted. So while on pause, I was lucky enough to score an initial eighteen month contract with the Department (Nov 1995). The job entailed about a fifty-fifty split between extension of science to develop and implement best management practices and doing research. During the tenure of this job, my supervisors and I managed to get the Sydney fires project back up and running thanks mostly to some additional support from Peter Fogarty and Bob Crouch in the form of some inter-departmental links and procurement of in-kind support. The field work for the project was duly completed in 1996 although it did take some more time to finish the analysis and write-up. The Thesis was finally submitted in early 1997.

Luckily my temporary contract became more temporary and then more permanent. As is generally the case now in Government departments, I have already witnessed several restructures (/reorganisations/realignments/reshuffles...), had several job titles and lines of management. Although this sort of thing is generally somewhat unsettling, I must admit that I feel I have benefited in that I've probably had the opportunity to work on a greater range of jobs and with more different disciplines than I otherwise would have. I also feel somewhat as a seasoned veteran despite a mere five and something years in the job - although my co-workers claim I am just ageing poorly. Perhaps I should apply to the Ulysses club for membership, a club for 'more mature' motorcyclists whose motto is to grow old disgracefully... but I digress.

Being based in Queanbeyan has been good for staying in touch with and actively collaborating with the CRC for Catchment Hydrology. In recent times my main involvement in CRC research has been by working with Ian Prosser in the Riparian Lands Program (the Jugiong in-stream wetlands project), and now in Project 2.1: "Sediment movement, water quality and physical habitat in large river systems' where I am currently searching the landscape for active gullies with Gary Caitcheon. Apart from that I have also been involved in developing a template water management plan for the Murrumbidgee Unregulated Streams Management Committee and more recently in modelling salt loads in the Hunter Catchment.

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LINKS TO KEY HYDROLOGY WEBSITES

If you want information about catchment hydrology, start with our website.

Our links pages feature a wide range of addresses and descriptions of key hydrological websites relevant to the land and water management industry.

The CRC web links database is updated weekly.

www.catchment.crc.org.au

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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 Land and Water Conservation, NSW
Department of Natural Resources, Qld
Department of Natural Resources and Environment, Vic
Goulburn-Murray Water
Griffith University
Melbourne Water
Monash University
Murray-Darling Basin Commission
Southern Rural Water
The University of Melbourne
Wimmera Mallee Water

Associates: SA Water • State Forests of NSW