

# An “integration blueprint” to underpin the development of the catchment modelling toolkit

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**Abstract:** The mission of the CRC for Catchment Hydrology 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*’. The primary method for delivery of this capability is a suite of software products known as the “Catchment Modelling Toolkit”. The CRCCH is now in its final three years and has made a \$30 million investment in a portfolio of 22 new research projects founded on a central integration objective. Models developed within each of these projects will populate the Toolkit and, when integrated, enable resource managers to undertake integrated assessment of catchment management options. The coordination required to achieve an integrated outcome is no trivial matter and we have dubbed the process and documents designed to provide this coordination as the “integration blueprint”.

Development of the integration blueprint has been an iterative process, integral to the development of new projects by research teams in areas of climate variability, land use change impacts on rivers, urban stormwater quality, river restoration, and water allocation. The iterations consisted of each team developing projects focused on the delivery of one or more modules; an analysis of the inputs required and outputs being provided by each; adjustments to projects to ensure matching of information type, temporal and spatial scale; an overall assessment of gaps in the project portfolio; further adjustments to projects by the project teams and so on. The development of such a large number of research projects in this way required a degree of cultural shift on behalf of the research teams. Each team had to develop a clear understanding of the requirements that other projects would have of their own work, be able to specify the detail of what they would need from other projects, and finally accept some level of “intervention” by those charged with ensuring the projects would indeed meet the CRCCH’s mission. In this paper we describe the outcomes of this process, illustrate how the project inputs and outputs are interlinked and discuss some of the key challenges in matching time and space scales and information type for tools intended to inform land-use and water management decisions at the whole-of-catchment scale.

**Keywords:** *Natural resource management; Environmental modelling; Integrated modelling*

## 1. INTRODUCTION

The mission of the CRC for Catchment Hydrology (CRCCH) 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*’.

This is complemented by our Vision Statement: ‘*Sustainable management of the nation’s water resources through adoption of an integrated approach to land-use, water allocation, hydrologic risk, and environmental values*’

The primary method for delivery of the mission is a suite of software products known as the ‘*Catchment Modelling Toolkit*’. The CRCCH is

now in its final three years and has made a \$30 million investment in a portfolio of 22 new research projects founded on a central integration objective. Models developed within each of these projects will populate the Toolkit and, when integrated, enable resource managers to undertake integrated assessment of catchment management options. A total of 158 staff (50 full-time equivalents), spread across 11 organisations are involved in the projects. The coordination required to achieve an integrated outcome is therefore no trivial matter. We have dubbed the process and documents designed to provide this coordination as the “integration blueprint”.

In this paper, we first describe the broad capability intended for the toolkit and then outline

the process followed during project development and implementation to help maximise the chances of an integrated outcome. We then summarise the projects and illustrate how these are interconnected.

## 2. INTENDED CAPABILITY OF THE TOOLKIT

### 2.1. Introduction

Based on the Centre's Mission and Vision statements, it is clear that the modelling tools developed over the next three years need to enable the *holistic prediction* of catchment behaviour at *large scales*, in response to *major land and water management options*. The italicised words provide a broad picture of the intended capability, but they are by no means prescriptive enough to found research projects upon. In this section we provide more detail on the modelling needs, including the scales of application and processes to be considered. Such information was provided to project teams as they began the process of developing the final suite of CRC projects.

### 2.2. Scale and spatial structure

Our ambition is to predict the hydrologic behaviour of large catchments, ranging in size between 10,000 and 160,000 km<sup>2</sup>. This is the scale of our five focus catchments (Yarra, Brisbane, Fitzroy, Murrumbidgee and Goulburn/Broken Rivers). We *have to* demonstrate a modelling capability at the focus catchment scale, but we also *want to* develop modelling capability at smaller scales. Hence, some of our projects are geared to deliver smaller scale models with more process detail. In our intended regional model structure, the focus catchments will comprise several hundred sub-catchments, interlinked by a river network of thousands to tens of thousands of kilometres in length. Gridded spatial data of elevation, land use and management, climate, geology and soils will be linked to this spatial structure. Software tools have been, or are being, developed in the Toolkit project to enable the presentation and analysis of spatial data and matching of scales.

### 2.3. Land and Water Processes

Our goal is to be able to predict the flow and load of sediment, nutrients and salt at any point in the river network of a focus catchment over time, at daily time steps, although results would be expected to be applied and assessed over periods of months to decades. A key to getting this right is linking processes on hillslopes to those in

groundwater and rivers (including riparian areas). We also seek the ability to predict the ecologic and economic impacts of changes in river flow and quality. Ecologic consequences will be limited to the changed habitat and ecologic health of the river system. Economic consequences will include both direct and opportunity costs.

### 2.4. Catchment Drivers

The primary catchment 'drivers' are considered to be climate, land use, land management, and river management. Economics will be considered, in our modelling, to be a secondary driver of catchment function. Our modelling capability must allow users to change these drivers to evaluate their impact on river flow and quality, and consequent ecologic and economic impacts.

In order to achieve the sort of capability outlined above, there has to be a strong emphasis on integration and coordination of the outcomes of individual research projects. In the following section, we describe the process and documents designed to provide this coordination. We then briefly overview the role of the programs and projects in meeting the CRC's mission, giving an example of how the projects link together. As the projects progress over the next three years, these specifications will be progressively refined and the blueprint will be updated.

## 3. THE 'INTEGRATION BLUEPRINT'

The initial development of the blueprint was an iterative process, integral to the development of new projects by teams in each of the CRCCH's research Programs, namely: 1. Catchment Prediction; 2. Impacts of Land Use Change; 3. Water Allocation; 4. Urban Stormwater Quality; 5. Climate Variability, and 6. Stream Restoration. The iterations consisted of each team developing

- projects focused on the delivery of one or more modules;
- an analysis of the inputs required and outputs being provided by each;
- adjustments to projects to ensure matching of information type, temporal and spatial scale;
- an overall assessment of gaps in the project portfolio;
- further adjustments to projects by the project teams and so on.

As each iteration took place, the detail of project inputs and outputs improved and the interdependency of projects within the final

portfolio became clearer. In the final stages of project development, attention was given to the timing of deliverables from detailed module specifications to software products. The development of such a large number of research projects in this way required a degree of cultural shift on behalf of the research teams. Each team had to develop a clear idea of how their own work fitted into the collective target modelling capability. For this to happen, each team had to develop a detailed understanding of the requirements that other projects would have of their own work, be able to specify the detail of what they would need from other projects, and finally had to accept some level of “intervention” by those charged with ensuring the projects would indeed meet the CRCCH’s mission.

The key to development of an integrated portfolio of projects is good two-way communication and a shared vision of what is needed to meet the mission. This was achieved through a series of meetings and project development workshops involving initially the Program leaders, and later all Project leaders.

Project development began in mid-2002, with the preparation of an initial set of project abstracts. The integration team went through each abstract to assess how the proposed project could fulfill part of the CRCs overall modelling needs. In some cases the fit was obvious, whereas in others the general area of work clearly fitted but the proposed research or development activity did not. To initiate integrative thinking amongst the project proponents, a “straw man” blueprint was developed and presented to Program leaders. This included for each project a table of expected modules, required inputs, expected outputs and comments on interactions with other projects. Where possible, comments on time and space scales were included. In many cases, the initial information in the tables was a “wish list”, rather than what was intended in the abstract. This provided a basis from which to build an achievable blueprint.

A series of meetings of Program leaders, Project leaders and the integration team progressively refined the blueprint and this permeated all of the final project agreements (contracts). These agreements included the dates for delivery of all project outputs. Part of the final preparation of project agreements included a check that the timing of outputs from each project matched the needs of others that needed the information as input to their own work. For this reason, several projects will deliver “first cut” models or modules relatively early to provide others something to work with and then progressively refine these, with final delivery in the last year of the project.

In this way, there can also be some iterative refinement of the needs of other projects. As they start to use these “first cut” models, requirements will become apparent that would otherwise have been difficult to envisage during project planning.

#### **4. AN INTEGRATED PORTFOLIO OF PROJECTS**

As noted above, the CRCCH has six research Programs with each focusing on a different aspect of catchment behaviour. The integration blueprint is directed towards ensuring that each individual project can focus its attention on development of a module/s that maximises the use of information from other projects, and provides other projects with appropriate information. For example, many projects require land use, soils and climate data, so one project focuses on providing that information to all the others. Similarly, estimates of the ecological impact of changes in hydrology or water quality are needed by several projects (eg. those looking at economic effects). In this case two linked projects deal with ecological indicators – one for urban areas and another for rural areas. In the following section, we overview the roles of each Program, and give some examples of how projects are linked.

Program 1 (Predicting Catchment Behaviour) has the overarching responsibility to deliver the modelling toolkit, based on the capability developed in the other Programs. It deals with software engineering issues, as well as the conceptual development needed for the integrated modelling products (eg. Vertessy et al., 2001). All of the modules from the other projects come together under Program 1. For example, information provided from other Programs includes: data and modules for stochastic rainfall generation; soils, terrain and land use data (developed for use by all projects); channel geometry (for use in routing at the catchment scale); modules to estimate the impacts of land use on water quality and quantity in both urban and rural environments (eg. Dawes et al., 2001; Dowling et al., 2003; Prosser et al., 2001; Tuteja et al., 2002; Vaze et al., 2003; Wong et al., 2001); modules simulating water allocation under different scenarios; economic indicators; and methods for aggregating/ disaggregating module input/output for matching time and space scales. Program 1 will develop network models to enable the various modules to be used in whole-of-catchment analyses.

The other programs focus on modules and models directed at particular components of the overall modelling capability. These are briefly described below. Figure 1 provides an overview of how the

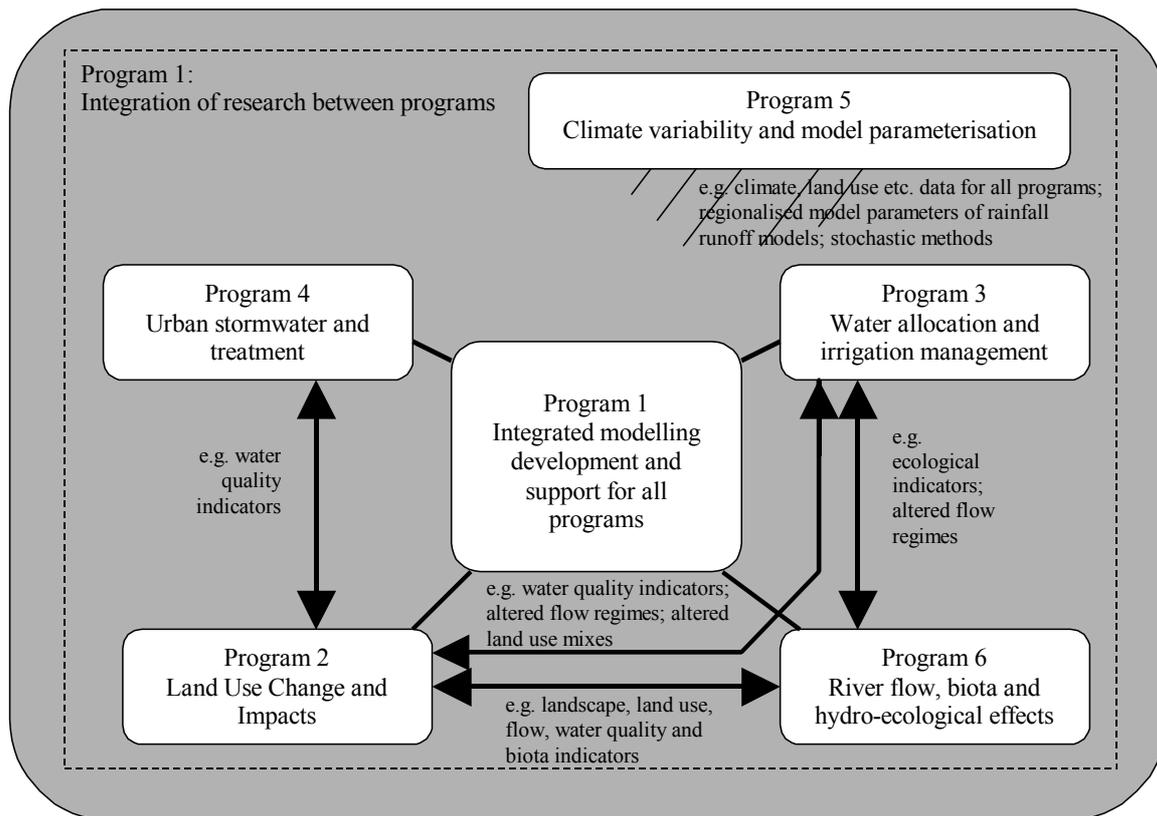


Figure 1. Integration paths between Research Programs of the CRCCH. Program 1 provides support and an integration focus between all programs.

projects fit together. However the real interaction is at the level of specific inputs and outputs and these are difficult to clearly show in a diagram. Grayson et al. (2003) describes the specific inputs and outputs from each project and how they link together. In the following paragraphs, the Program inputs and outputs are described in general terms.

Program 2 (Impacts of Land Use Change on Rivers) has five projects focused on the effects on water quality and quantity of different types of land use change. The water quality parameters of interest are salt, sediment, phosphorous and nitrogen. One project focuses on the effects of irrigation, while the others relate to dryland management. The generation and delivery of salt, sediment and nutrients are the focus of these projects, including the effects on delivery of stream networks, floodplains and riparian zones.

Inputs required: climate, flow and landscape data from Program 5; water allocation information from Program 3; parameters for economic assessment from Program 3; channel metrics from Program 6;

Outputs provided: irrigation demand requirement, extraction quantity, drainage quantity and salinity; sed/nut loads in size classes at the hillslope, reach scales (methods to

disaggregate these to daily from Program 1); erosion/deposition at the larger scales (TSS, TP, TN, dissolved and particulate N, P); daily salt load at sub-catchment outlets, area of salt affected surface, methods for extrapolating results from catchments where applied in detail to other areas; flow duration curves for different land-use scenarios

Program 3 (Sustainable Water Allocation) focuses on methods to analyse irrigation systems, taking into consideration water availability, water quality, economic performance, and water distribution system constraints. The Program integrates biophysical and socio-economic models to generate catchment flow regimes for different land and water management policy options. These will be used to assess the social and economic consequences of altered flow regimes (which include changes in water quality and may lead to further constraints on flows or land use and management) and so enable iterative assessment of economic and environmental consequences of management actions.

Inputs required: output from the IQQM/REALM water allocation models, input/output (I/O) analysis tables for focus catchments, ecological indicators from Program 6, water

quality from Program 2, stochastic climate data from Program 5.

Outputs provided: multipliers from I/O analyses, altered land use mix based on integrated system analysis

Program 4 (Urban Stormwater Quality) focuses on the further development of MUSIC (Wong et al., 2001), including making it more modular to enable integration with catchment-scale models. Future versions of MUSIC will include economic and ecological analysis modules, and consider additional treatment options and water quality parameters.

Inputs required: climate and landscape data, costs of treatment options, output from Program 2

Outputs provided: daily flows, TSS, TP, TN, metals for urban areas – some size partitioning, treatment performance in terms of deposition/ sequestration and economic performance, ecological consequences of flow (with Program 6), lifecycle costs

Program 5 (Climate Variability) is responsible for the provision of major data sets required by most projects. These include regionalised hydrological model parameters that reflect the effects of land use change and the development of methods for stochastic generation of spatio-temporal rainfall sequences/fields. In addition, there is a focus on improving the land surface modelling used in weather forecasting.

Inputs required: flow duration information from Program 2; rainfall-runoff models from Program 1; specifications for soils, land use and vegetation information from other projects; rainfall data from existing data bases

Outputs provided: spatial landscape data (vegetation, soils, land use, terrain); rainfall forecasts; modules to stochastically generate sequences of daily space/time rainfall fields and sub-daily point rainfall

Program 6 (River Restoration) focuses on river flow-biota interactions, and the prediction of channel geometry enabling the prediction of the ecological impacts of river management, landuse change and changes in water quality. These ecological effects will also be used in the economic impact modelling within Program 3. The channel geometry work is particularly useful in Programs 2 and 1.

Inputs required: landscape and flow data; changes to hydrological/hydraulic response due to land use change; particle size information on transported sediment

Outputs provided: ecologically meaningful metrics based on flow; metrics for predicting channel form and physical habitat; trajectory of changes based on management scenarios.

## 5. CONCLUSIONS

Meeting the mission of the CRCCH requires development of a suite of software tools that are integrated across a range of scales and resource management issues. The development of a project portfolio to provide this capability required a high level of coordination, underpinned by a shared vision between project teams. An “integration blueprint” was developed as part of this coordination. This blueprint summarised project inputs, outputs and capabilities and matched these with the needs of other projects and of the CRC as a whole. The blueprint will be refined as the projects progress and the Toolkit becomes populated with operational modules and models.

## 6. ACKNOWLEDGEMENTS

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