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CSIRO Land and Water Technical Report No. 11/04
March 2004

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Reference

This document should be referenced as:

Newham, L.T.H., Cuddy, S.M., Vertessy, R.A. and Jakeman, A.J. (2004) Informing the design of catchment contaminant cycle modelling – a survey of end-user needs. CSIRO Land and Water Technical Report 11/04. CSIRO Land and Water, Canberra.

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ISSN1446-6171

Informing the design of catchment contaminant cycle modelling

– a survey of end-user needs

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CSIRO Land and Water Technical Report No. 11/04
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KEY RESULTS SUMMARY

This report documents the results of a survey of potential and actual end-users of contaminant cycle models in Australia held in late 2003. The survey was conducted as part of a research project to build a catchment contaminant cycle model for stakeholder use and is a core source of design guidelines for the model. The project is a collaborative endeavour between CSIRO Land and Water, the Integrated Catchment Assessment and Management (iCAM) Centre of The Australian National University and the Cooperative Research Centre for Catchment Hydrology and is underwritten by Land and Water Australia and the Murray Darling Basin Commission through their National River Contaminant Program. The end result will be a new model reflecting current stakeholder needs and the most recent science.

Several key conclusions can be drawn from the survey results:

- A capacity to model sediment, nutrient and salt fluxes is a minimum requirement of contaminant cycle models. The process representation necessary to simulate these contaminants provides a robust basis for the simulation of a variety of other contaminants which are very often context and/or catchment specific.
- A capacity to simulate the effects of common types of management interventions, importantly landuse change, riparian zone management, flow management and point source control, is a minimum requirement for inclusion in contaminant cycle models.
- A capacity to simulate the effects of contaminant loadings on ecological functioning and habitat values should be considered for inclusion as an integral part of contaminant cycle models. End-users ranked floodplain and riparian vegetation, macroinvertebrate population and algal biomass measures and indicators highly in that context.
- Contaminant cycle models need to be applicable across a relatively large range of spatial scales to meet the needs of a variety of end-user groups.
- The results from contaminant cycle models need to be effectively communicated to end-users. For effective communication, simple methods of representing the outputs of contaminant cycle models, for example maps, are preferred by the majority of end-users.
- Improvements are required in the estimation and representation of uncertainty in model outputs.

1 INTRODUCTION

An ability to describe and explore the relationships between management activities and land and water conditions is critical to maintaining and restoring the ecological health and function of stream and catchment systems. Appropriately constructed models are needed to assist end-users to identify sources, pathways, interactions and impacts of contaminants through a catchment landscape and its waterways. In this context, land and water managers are increasing their reliance on computer models to support their decision making for the management of stream contaminants.

The involvement of end-users in the model development process is critical to the success and adoption of contaminant cycle models. Close interaction is required to establish how and when models are used and identify those features that support and/or inhibit their use. This report presents results from a survey of model end-users conducted in late 2003 to assist model developers to construct models that meet the requirements and preferences of end-users. The report describes the design of the survey and an analysis of the results, including a collation of general comments of survey respondents. The results are then discussed in light of their implications for the development of future contaminant cycle models.

2 METHODS

The survey was one of a series of activities designed to seek input and feedback on current stakeholder needs. The outcomes from a series of workshops, held during 2003 and 2004, are being documented in companion reports.

2.1 Survey Design

The purpose of the survey was to collect input on key aspects relevant to the development of contaminant cycle models. Information was sought on issues such as:

- the contaminants that should be modelled;
- the types of management interventions that should be simulated;
- the ecological and habitat value indicators of interest;
- technical issues, e.g. at what spatial extent should models be applied; and
- how model results should be communicated.

Preparation of the survey was a challenging task. For practical reasons there was a need to limit the number of questions included in the survey. The aim was to restrict the time required to complete the survey to under 15 minutes. There was also a need to balance the requirement for inclusion of detailed scientific and technical information in a questionnaire that could be understood by a broad range of end-users. A draft questionnaire was prepared and circulated among technical specialists, end-users and web-developers for critical comment. The content and format of the survey was revised in the light of these comments. The 15 survey questions are listed in Appendix 1.

The survey was implemented and delivered using an online survey tool and provider¹. Figure 1 shows a view of one page of the online survey questionnaire.

1. Your Background

What activity are you mainly involved in? (please check one box)

Research

Management

Consulting

Teaching

Community Representation

Policy Development

What is your primary involvement with models? (please check one box)

I develop them

I evaluate/test them

I use them in my work

I commission their use

What is your primary interest in management of contaminants? (please check one box)

Regional planning

River restoration

Water quality improvement

Fish restoration

Land use change

2. Pollutants

Please rate the following pollutants according to your view of their importance for sustainable catchment management (please check one box for each contaminant)

(1 - very important, 5 - not important)

Sediment - Total load

1 2 3 4 5 N/A

Figure 1, A view of the online survey questionnaire using the eSurveys.com.au framework

An invitation to participate in the survey was sent via email to over 1,000 people. The mailing list included a broad range of managers, researchers, consultants and others generally concerned with the application and development of contaminant cycle models.

2.2 Analysis of Results

All responses to the survey were recorded using the internet-based survey tool which provided flexible reporting and analytic function during and post the survey collection phase.

Most issues were expressed as questions requiring ranking on an open numbered scale between 'not important' (score 1) and 'very important' (score 5). Respondents were able to rank their response within this range (scores 2, 3 and 4 did not have an associated description). To enable comparison between questions, some of which were answered by different numbers of respondents, the average

¹ The survey was delivered using the eSurveys.com.au framework, a leading Australian internet-based online survey tool, designed and hosted by Alfresco Design Pty Ltd (www.alfresco.com.au)

overall score was calculated for each question. The same technique has been applied to determine the scores of various groups of respondents e.g. managers or consultants. In this report results are generally tabulated with an accompanying discussion of pertinent points.

3 RESULTS

A total of 255 responses to the survey were recorded — of these 176 were complete. The survey return rate (a little over 20%) was reasonable for a survey of this type. The survey grouped questions into 5 sections:

- 1 – background of the respondent
- 2 – contaminants of interest
- 3 – management interventions
- 4 - ecological and habitat value indicators
- 5 - technical issues.

3.1 Background

Q1. What activity are you mainly involved in?

The first section of the survey gathered information on the background of the survey respondents. Collection of this information enabled responses to be classified. Respondents were asked their primary activity (from a list of 6) and could only check one. Table 1 summarises these activities, ordered by proportion.

Table 1, Primary activity of survey respondents

| Primary Activity | Proportion of respondents |
|--------------------------|----------------------------------|
| Research | 36% |
| Management | 27% |
| Consulting | 23% |
| Policy development | 10% |
| Community representation | 4% |
| Teaching | 1% |

A broad range of end-users completed the survey. The combined proportion of respondents that were involved in management, consulting or policy development activities was 60%. Community representatives and teachers were under represented in the survey possibly reflecting limited

distribution of the survey to these groups. It is recommended that further investigation into the modelling needs and preferences of these under-represented groups be explored.

Q2. What is your primary involvement with models?

Table 2 provides a summary of the level of involvement with models that survey respondents reported, ordered by proportion.

Table 2, Level of involvement of survey respondents with models

| Primary involvement | Proportion of respondents |
|------------------------|---------------------------|
| I use them in my work | 67% |
| I commission their use | 15% |
| I develop them | 14% |
| I evaluate/test them | 4% |

The majority of respondents (67%) used models in their work. Of the respondents that gave development as their primary involvement with models, 69% of those were researchers and 20% were consultants. Very few policy developers or managers developed their own models emphasising the need for close interaction between researchers and consultants in the process of model development.

Q3. What is your interest in management of contaminants?

Table 3 is a summary of the primary interests of respondents in the management of contaminants, expressed as a proportion (%) of the total number of respondents. The categories are stratified according to their activity type.

Table 3, Primary interest in the management of contaminants stratified by activity type

| | Landuse change | Regional planning | River restoration | Water quality improvement | Total |
|--------------------------|----------------|-------------------|-------------------|---------------------------|------------|
| Research | 14 | 6 | 3 | 13 | 36 |
| Management | 3 | 5 | 4 | 15 | 27 |
| Consulting | 6 | 3 | 2 | 12 | 23 |
| Policy development | 3 | 2 | - | 4 | 9 |
| Community representation | 1 | - | - | 3 | 4 |
| Teaching | 1 | - | - | - | 1 |
| Total | 28 | 16 | 9 | 47 | 100 |

The primary interest in the management of contaminants is for water quality improvement (47%) followed by landuse change (28%). Interestingly, managers and consultants were more interested in water quality improvement than researchers and policy developers who showed more interest in the impacts of landuse change on contaminants.

3.2 Contaminants

A fundamental consideration for the development of contaminant cycle models is the suite of contaminants that are simulated.

Q4. Please rate the following contaminants according to your view of their importance for sustainable catchment management.

Table 4 shows the overall importance score for each of the contaminants listed in the survey. High numbers indicate a higher importance to survey respondents.

Table 4, End-user importance scores for various contaminants

| Contaminant | Overall score | Consulting | Management | Policy development | Research |
|-------------------------------|---------------|------------|------------|--------------------|----------|
| Suspended sediment | 3.11 | 3.25 | 3.16 | 2.72 | 3.06 |
| Total phosphorus | 3.09 | 3.25 | 3.12 | 3.04 | 3.00 |
| Salt | 3.07 | 2.96 | 2.87 | 3.08 | 3.28 |
| Sediment (total load) | 2.99 | 3.04 | 3.03 | 2.84 | 2.98 |
| Total nitrogen | 2.98 | 3.23 | 3.01 | 2.72 | 2.86 |
| Filterable reactive phosphate | 2.86 | 2.86 | 2.86 | 2.72 | 2.91 |
| Pesticides | 2.86 | 2.84 | 2.72 | 2.72 | 3.02 |
| Sediment (turbidity) | 2.83 | 2.91 | 3.00 | 2.76 | 2.64 |
| Oxides of nitrogen | 2.71 | 2.84 | 2.63 | 2.35 | 2.77 |
| Pathogens | 2.69 | 2.63 | 2.66 | 2.75 | 2.69 |
| Ammonium | 2.62 | 2.74 | 2.54 | 2.57 | 2.59 |
| Bedload sediment | 2.39 | 2.37 | 2.43 | 2.46 | 2.30 |
| Water temperature | 2.17 | 2.14 | 2.09 | 2.43 | 2.11 |

The three contaminants with the highest importance scores were suspended sediment, total phosphorus and salt. The three contaminants with the lowest scores were ammonium, bedload sediment and water temperature (thermal pollution). Interestingly, salt, pesticides and pathogens were more often considered 'very important' relative to their overall score.

There were some variations between end-user groups in their score of the importance of the various contaminants. Relative to the overall score, researchers ranked salt and pesticides highly, possibly reflecting their own research interests. Managers and consultants showed similar importance scores for most contaminants. Managers assigned a lower importance to salt and higher importance to turbidity than the overall score. Consultants gave total nitrogen a higher score than the other groups.

Survey respondents were also given the opportunity to note contaminants that they considered important but were not listed in the survey questionnaire. A wide variety of contaminants were listed including:

- acidity
- heavy metals
- gross pollutants
- colour
- dissolved oxygen
- hydrocarbons, and
- endocrine disruptors.

3.3 Management Interventions

An ability to explore the relationships between management activities and resultant land and water conditions is a critical function of contaminant cycle models. Survey respondents were given an opportunity to rate the importance of a variety of management interventions and also to list any additional management interventions that they considered should be included in contaminant models.

Q5. Please rate the following management intervention options according to your view of their importance for inclusion in a catchment contaminant cycle model.

Table 5 shows the importance for each of the management interventions listed in the survey ordered by Overall score. High numbers indicate higher importance for the management interventions.

Landuse change, followed by riparian zone management and point source control were considered the most important management interventions for simulation in a contaminant cycle model.

Consultants and researchers ranked flow management highly relative to its overall score. Managers, on the other hand, ranked riparian zone management as the most important management intervention for inclusion in contaminant cycle models.

Table 5, End-user importance scores for various management interventions

| Management intervention | Overall score | Consultants | Managers | Policy development | Research |
|--------------------------|---------------|-------------|----------|--------------------|----------|
| Landuse change | 3.44 | 3.48 | 3.28 | 3.42 | 3.52 |
| Riparian zone management | 3.28 | 3.28 | 3.30 | 3.37 | 3.17 |
| Point source control | 2.99 | 3.15 | 2.98 | 3.00 | 2.89 |
| WQ improvement devices | 2.94 | 3.16 | 2.71 | 2.95 | 2.92 |
| Flow management | 2.93 | 2.93 | 2.76 | 2.89 | 3.00 |
| River bank stabilisation | 2.88 | 2.98 | 2.91 | 3.05 | 2.70 |
| Gully stabilization | 2.77 | 2.96 | 2.78 | 2.61 | 2.61 |
| Stocking management | 2.66 | 2.54 | 2.77 | 2.58 | 2.61 |
| Tillage practices | 2.47 | 2.37 | 2.65 | 2.11 | 2.41 |
| Groundwater pumping | 2.42 | 2.35 | 2.39 | 2.11 | 2.48 |
| Evaporation basins | 1.99 | 2.18 | 1.88 | 1.76 | 1.99 |

Survey respondents were also given the opportunity to note any management interventions that they considered important but were not listed in the survey questionnaire. A variety of additional interventions were suggested by respondents including:

- water storages
- sand and gravel extraction
- education efforts and best management practices
- fertilizer management
- improved irrigation technology
- water diversions, extractions and environmental flows
- recharge management
- urban influences, and
- septic tanks and effluent management.

3.4 Ecological and Habitat Value Indicators

The impact of contaminants on the ecological function of riparian areas and on associated habitat suitability is of great interest for prioritising the management of contaminants. The survey included questions on the importance of both ecological indicators and also habitat value indicators.

Q6. Please rate the following ecologic indicators according to your view of their importance of inclusion in a catchment contaminant cycle model.

Table 6 shows the importance of ecological indicators as ranked by survey respondents. High numbers indicate higher importance for the management interventions.

Table 6, End-user importance scores for various ecological indicators

| Ecological indicator | Overall score | Consulting | Management | Policy development | Research |
|--|----------------------|-------------------|-------------------|---------------------------|-----------------|
| Floodplain and riparian vegetation condition | 3.05 | 3.07 | 2.91 | 3.19 | 3.07 |
| Macroinvertebrate population | 2.86 | 2.85 | 3.07 | 2.61 | 2.70 |
| Algal biomass | 2.77 | 2.63 | 2.87 | 2.67 | 2.78 |
| Native fish population | 2.75 | 2.61 | 2.77 | 2.65 | 2.76 |
| Gross primary production | 2.67 | 2.78 | 2.57 | 1.93 | 2.81 |
| Water bird population | 2.34 | 2.35 | 2.36 | 2.24 | 2.25 |
| Respiration | 2.32 | 2.32 | 2.23 | 1.73 | 2.46 |

'Floodplain and riparian vegetation condition' was the most highly ranked indicator.

Macroinvertebrates, algal biomass and native fish population were also highly ranked. Managers ranked macroinvertebrates more highly than its overall score. Consultants and research groups both ranked gross primary production more highly than its overall score, similarly policy developers ranked algal biomass highly.

Q7. Please rate the following indicators of habitat value according to your view of their importance for inclusion in a catchment contaminant cycle model

Table 7 shows the score of the importance associated with habitat value indicators by survey respondents.

Table 7, End-user importance scores of various habitat value indicators

| Habitat indicator | Overall score | Consulting | Management | Policy development | Research |
|-----------------------|---------------|------------|------------|--------------------|----------|
| Substrate type | 2.87 | 2.89 | 2.85 | 2.82 | 2.86 |
| Pool/riffle sequences | 2.72 | 2.62 | 2.63 | 3.06 | 2.70 |
| Riparian shading | 2.68 | 2.51 | 2.82 | 2.71 | 2.57 |
| Large woody debris | 2.64 | 2.57 | 2.69 | 2.89 | 2.51 |

Overall the substrate type (e.g. bedrock, sand and mud) was of greatest importance as an indicator of habitat value. Managers and policy developers attached different importance to the listed habitat values e.g., policy developers viewed pool/riffle sequences and the occurrence of large woody debris as the most important indicators of habitat value.

Survey respondents were also given the opportunity to note any ecological or habitat value indicators that they considered important but were not listed in the survey questionnaire. A variety of additional ecological indicators were suggested, including:

- primary contact and human health
- impacts on marine environments e.g. estuarine fisheries and oyster productivity
- introduced and pest species
- vertebrates
- macrophyte biomass
- groundwater condition
- icon species
- blue-green algae
- benthic metabolism, and
- stock health.

A similar variety of habitat values was considered important by respondents, including:

- inundation of riparian wetlands
- pool destratification potential
- in-stream vegetation

- lateral flow connectivity
- width of riparian strip
- vegetation type and composition
- channel and floodplain connections
- submerged macrophyte content
- stream channel profile geometry, and
- hydraulic diversity.

3.5 Technical Issues

Input from survey respondents was sought on a variety of technical aspects related to the development of contaminant cycle models. The responses to these questions are presented in the sections below.

3.5.1 Spatial and Temporal Resolution

The survey included questions concerning the spatial and temporal resolution at which end-users consider contaminant cycle models should be applied.

Q8. Please rate the following catchment sizes according to your view of the spatial extent that a contaminant cycle model should be applied at.

The overall scores of respondents are tabulated in Table 8.

Table 8, Summary of preferences for spatial extent of model application

| Spatial extent (km ²) | Overall score | Consulting | Management | Policy development | Research |
|-----------------------------------|---------------|------------|------------|--------------------|----------|
| 0-1 | 2.16 | 2.74 | 2.16 | 2.07 | 1.83 |
| 10 - 100 | 2.75 | 3.24 | 2.86 | 2.59 | 2.42 |
| 10-100 | 3.02 | 3.07 | 3.22 | 2.71 | 2.86 |
| 100-1000 | 3.00 | 2.76 | 2.96 | 2.87 | 3.18 |
| 1000-10000 | 2.56 | 2.24 | 2.43 | 2.93 | 2.77 |
| 10000-100000 | 2.13 | 1.83 | 2.10 | 2.53 | 2.22 |
| >100000 | 1.62 | 1.33 | 1.45 | 2.20 | 1.77 |

Table 8 shows that, collectively, survey respondents believe that models should be applied at spatial scales ranging between 10km and 100km². However, there are some differences between end-user

groups. Consultants and managers place greatest importance in smaller scale model applications with a mode in the 10-100km² category. Policy developers on the other hand show a larger scale perspective placing greatest importance on the 1000-10000km² category. Researchers occupy the middle ground placing greatest importance in the 100-1000km² category.

Q9. Please rate the following time intervals according to your view of how a catchment contaminant cycle model should operate.

Survey respondents showed a preference for daily and higher time intervals for the operation of contaminant cycle models. There was only minor variation between the preferences of each of the end-user groups. Several respondents commented that this question was of a technical nature and hence better addressed by model developers.

3.5.2 Climate Inputs

Climate is a key determinant of many processes associated with contaminant source, transport and fate and is therefore an important consideration in the development of contaminant cycle models.

Q10. Please rate the following types of climate inputs according to your view of their importance as inputs to catchment contaminant cycle models.

Table 9 presents results from the survey on the preferences of model users for climate driving sequences.

Table 9, Summary of preferences for climate driving sequences

| Climate input | Overall score | Consulting | Management | Policy development | Research |
|--|---------------|------------|------------|--------------------|----------|
| Historic | 3.16 | 3.26 | 2.96 | 2.80 | 3.26 |
| Representative (e.g. average/dry/wet) | 3.08 | 2.98 | 3.16 | 2.63 | 3.18 |
| Synthetically generated | 2.68 | 2.90 | 2.80 | 2.47 | 2.52 |

Survey respondents show a preference for historic climate sequences as inputs to contaminant cycle models. This is consistent across all user groups with the exception of managers who show a slight preference for representative climate sequences.

3.6 Communicating Results

It is critical that the results from contaminant cycle models are effectively communicated to end-users. The survey was used to collect information on the preferences of survey respondents for representing measures of the quantities of contaminants and the methods used to communicate these results.

Q11. Please rate the following measures of contaminants according to your view of their usefulness as outputs from catchment contaminant cycle models

Table 10 shows the preferences of survey respondents for representing contaminant quantities.

Table 10, Summary of the preferences of survey respondents for representing contaminant quantities

| Contaminant measure | Overall score | Consulting | Management | Policy development | Research |
|--------------------------------|----------------------|-------------------|-------------------|---------------------------|-----------------|
| Annual total loads | 3.05 | 2.95 | 2.98 | 3.21 | 3.14 |
| Monthly total loads | 2.92 | 2.82 | 2.92 | 2.79 | 2.97 |
| Long term average annual load | 2.85 | 2.95 | 2.80 | 2.57 | 2.87 |
| Monthly average concentrations | 2.76 | 2.82 | 2.76 | 2.57 | 2.70 |
| Annual average concentrations | 2.73 | 2.82 | 2.69 | 2.43 | 2.73 |
| Daily concentrations | 2.44 | 2.36 | 2.42 | 2.79 | 2.44 |
| Daily loads | 2.40 | 2.30 | 2.39 | 2.43 | 2.50 |

Q12. Please rate the following spatial units according to your view of their importance for reporting results from a catchment contaminant cycle model.

Table 11 presents a summary of the preferences of survey participants for the units used to report results from contaminant cycle models. The general preference of respondents was for results to be presented at subcatchment and stream reach units.

Table 11, Summary of the preferences of survey respondents for the spatial units at which results from contaminant cycle models are reported

| Contaminant measure | Overall score | Consulting | Management | Policy development | Research |
|----------------------------|----------------------|-------------------|-------------------|---------------------------|-----------------|
| Catchment outlet | 2.86 | 2.82 | 2.71 | 2.60 | 3.08 |
| Subcatchment | 3.38 | 3.48 | 3.19 | 3.07 | 3.50 |
| Hillslope | 2.24 | 2.33 | 2.06 | 2.07 | 2.28 |
| Hillslope segment | 1.91 | 1.93 | 1.79 | 2.00 | 1.91 |
| Stream reach | 2.85 | 3.15 | 2.83 | 2.71 | 2.64 |

Q13. Please rate the following kinds of data visualization according to your view of their usefulness for stakeholders.

Table 12 shows a summary of the preferences of survey respondents for data visualisation from catchment contaminant cycle models.

Table 12, Summary of the preferences of survey respondents for data visualisation

| Data | Overall score | Consulting | Management | Policy development | Research |
|----------------------------------|----------------------|-------------------|-------------------|---------------------------|-----------------|
| Maps | 3.61 | 3.72 | 3.66 | 3.60 | 3.53 |
| Time series | 3.24 | 3.15 | 3.04 | 3.23 | 3.44 |
| Probability of exceedence graphs | 2.74 | 3.00 | 2.52 | 2.38 | 2.80 |
| Tabular reports | 2.55 | 2.90 | 2.26 | 2.36 | 2.53 |
| Box plots | 2.37 | 2.39 | 2.38 | 2.07 | 2.33 |
| Animations | 2.34 | 2.49 | 2.51 | 2.07 | 2.20 |

The majority of survey respondents were most interested in simple methods of data visualisation. There was a clear preference across all user groups for maps as a method of data visualisation. Some minor variations between the preferences of end-user groups were observed however these generally occurred among the least preferred methods of data visualisation.

3.7 General Comments

Survey respondents were given an opportunity to provide additional comment concerning the development and use of contaminant cycle models in a general comments section. The comments section enabled respondents to provide additional information on issues that they considered were not sufficiently detailed in the survey and was also used by respondents as a forum to raise concerns regarding general model development activities.

The issues raised by individual respondents should not be considered representative of all end-users; they do however provide useful material to consider for the ongoing development of contaminant cycle models. Approximately 70 respondents provided additional comments concerning the development and use of the contaminant cycle models. These responses are summarised in the sections below under several broad categories. Some minor editing of the comments has been undertaken.

3.7.1 Model Integration

Suggestions were made by several respondents concerning the integration of contaminant cycle models with other types of models and information, e.g.:

'Models should be able to incorporate a selection of hydrological models.'

'Contaminant/nutrient generation and cycling models should be able to encompass other inputs/models - i.e. they should be able to be 'linked' with other models (perhaps GIS based) to enable comparison of inputs; and model outputs as the majority of models are based on limited information and are only as useful (and accurate) as the accuracy of their respective input data.'

'I am concerned that the modelling process being adopted is a static one which is not going to do the sort of work required to develop long term interpretive and interactive assessment of landuse and fiscal policy development and testing. I see the inputs into this model as being factors that can be incorporated into a broader and more useful tool to enable the use of objective current and historical data to test impacts on the river environment.'

Comments also concerned the integration of models into other decision and assessment frameworks:

'Any model should encompass a threat or risk assessment to enable land managers to help determine hotspots.'

'While analytical models provide important information - it is important to use tools such as DSS/Bayesian Belief Networks to develop conceptual models - to quantify the source of water quality contaminants and transport processes.'

'I'd like to see the development of risk based ecological assessments that use stochastic models to assess risks; developed in partnership with stakeholders.'

3.7.2 End-user Consultation

Respondents were supportive of incorporating end-user consultation activities as an integral part of the model development process, e.g.:

'This is an excellent initiative which would have far reaching benefits for the sustainable development and protection of environment.'

'I hope there will be strong involvement of actual end users in project specification in order to ensure designed model outputs are what are needed; confidence levels are clear; and model complexity is commensurate with data availability; understanding of processes; uncertainty; and resource availability for using the model.'

'Communication does not start with the launch of the model. Development of the model should be participative; at least on a technical basis. Too many projects argue that they first need to develop and then start talking.'

There were also comments on the failure of end-user consultation processes:

'There is much confusion about lots of different models and what they can do for catchment management.'

'There is a need to make sure that those of us who lack detailed knowledge of the models but are interested in the outputs from them, are clear on what each of the different models is trying to achieve and how they all fit together.'

3.7.3 Model Usability

Model usability was a concern for a small number of survey respondents, e.g.:

'It must be easy to input data and amend data once in the model (i.e. don't have to re-load the entire set if a minor change is required). Similarly outputs must be easily exported and manipulated and can be represented in a variety of ways.'

'Need to be able to input as much local data for an area of study as possible but also have standard input data if this information is not available.'

'The model must be exportable to programs such as ARCINFO.'

3.7.4 Contaminants

Several respondents expressed that the importance of contaminants is often context specific, e.g.:

'The importance of issues is related to the type and location of the catchment. Marine versus freshwater; high rainfall versus low flows; small coastal catchments versus large inland catchments.'

'Importance of different contaminants varies considerably from area to area so hard to rank them. Salt may be more important in one catchment than pesticides or vice versa.'

There were other more detailed comments concerning contaminants, e.g.:

'Need to consider sediment and biota accumulated contaminants together where possible.'

3.7.5 Role in Decision Making

Several survey respondents commented on the role of contaminant cycle models in the decision making process:

'Models should be properly put in context as to their accuracy and utility in the overall catchment management framework. An emphasis should be placed upon not only creating a model that works; but also allowing for a reasonable understanding of the statistical accuracy of the model to be made with all outputs - people have a dangerous tendency to read numbers and accept them; regardless of their source or accuracy - meaning that decisions can be made based on poor data.'

'Need to be grounded in cycles of adaptive management with local stakeholders.'

'A model that is effective for all temporal and spatial scales; all management techniques; all landuse influences; that provides all output formats etc. would be fantastic but such attempts usually compromise on all aspects.'

'Link to direct use in catchment blueprint reporting.'

'Most models fail because either so general as to be useless for policy or landuse management or are so detailed that they are only applicable to one small area.'

'I think it needs to be made very clear to community groups that when they want to use this or similar models e.g. SedNet. EMSS for their catchment prioritisation there is a minimum data set required at a certain scale and or quality rating if they want to use the models to prioritise where on ground works should occur in catchment. From experience if model is run for a catchment regardless of input data quality output then becomes the truth and this is a concern for scientists.'

3.7.6 Uncertainty

There were many comments concerning how uncertainty is dealt with in contaminant cycle modelling:

'I think it is important to point out to end-users the uncertainty of model outputs; in a manner they will understand. Not necessarily the detailed statistics; but enough so they can work out how much the model depends on extrapolation or fudging/fitting. Then they can judge if it is any better than a qualitative approach.'

'Need to represent sensitivities in a way understandable by people without specialist modelling expertise.'

'There is a danger that those using the model do not fully understand the inputs/outputs and take the black box approach. Full understanding of the parameters and interactions is needed by users to ensure that realistic modelling occurs.'

'Assumptions the level of validation and also any limitations to the use of the model need to be made clear.'

'Unwarranted complexity in models should be avoided.'

'A model without validation is only half of the story.'

'Error estimation and variance indications must be included in results.'

'Model outputs and the way they were obtained need to be transparent to all users.'

3.7.7 Scale Issues

There were also a number of comments on temporal and spatial scale issues such as:

'Managers will be interested in different measures and timescales for different contaminants; e.g. annual phosphorus loads may be much more important than daily phosphorus concentration; but the reverse may be true for pathogens and pesticides.'

'The model must be able to handle the long time delays in salinity response to landuse change. Predictions or outputs should indicate the reliability of predictions and give a range of numbers.'

'The availability and quality of data to calibrate the model will need to be considered prior to scale setting - most contaminant data is collected only on a monthly basis.'

'The questions regarding scale of the investigation/study area are difficult to answer because if the target area is small a detailed study then the data requirements will probably be daily; whereas when investigating larger areas monthly or annual data may be sufficient.'

'Not clear whether catchment cycle model is to link the generation and transport of contaminants in the catchment with the ecological effects in the downstream water bodies (rivers; wetlands; estuary?). Some questions suggest this may be an aim. If so this will be challenging and it will be very important that the knowledge-based used to determine the relationships between contaminants and ecological effects are clearly and transparently stated. It is important to identify all major uncertainties.'

'An ability to assess cumulative impact with respect to the treatment of diffuse source pollutants (mainly sediment and nutrients) is important to assess the overall impact of individual small projects which can be widely separated both spatially and temporally.'

'Nice to ask people the scale of outputs etc they would like to see but I am sceptical that these could be produced with any real level of reliability in some cases. You need to think through how to balance these stakeholder needs with the realities of the model capacity at these scales and how this can be conveyed through an interface.'

3.7.8 Communication

Numerous survey respondents submitted comments concerning communication activities associated with contaminant cycle modelling e.g.:

'Professionals and community groups need to be adequately trained in understanding the selected model and in interpreting data. They should also be trained in collecting and submitting data to drive the model.'

'From a teaching point of view a catchment model could be a great tool for illustrating over all catchment effects. However for use at this level it would need to be fairly accessible and not too complex. Maybe it could have filters which could be used to simplify the model so that landowners or students with no great technical knowledge could look at particular aspects.'

'I think it is important for the model to be flexible in its inputs and outputs, e.g. results presented as a map are more easily communicated but if the model is being used over a period of time to determine the effect of work a time series may be more useful.'

'Different levels of models should be developed as outputs to suit particular communication needs; and also the time imperatives of catchment managers to keep work going; and modify actions/focus as understanding improves. Avoid analysis paralysis.'

'Seldom come down to individual landholder/manager level; so difficult to engage at a level which will bring about change of management. However, models are very useful at a policy/overall catchment sensitivity level. Farmers find models of limited usefulness in managing their problems. Need derived material to engage land managers.'

'I feel models are underused by community/ governments and therefore require some simplification to enable continual community involvement and interest to push management projects forward for sub catchment management practices.'

'Both load and concentration are valuable ways to present the model outputs; depending on the parameter considered, e.g. concentration is important for assessing within-reach effects of high nutrient levels; and total load is important for assessing the impact on receiving waters.'

3.7.9 Miscellaneous Comments

There were other miscellaneous comments that did not fit easily within any of the categories:

'This could be either used for a day to day operational management; which would require daily info/small catchments; etc; or for a whole-of-catchment strategy; where the info would need to be available for larger catchments; maybe monthly or annually. Managers will probably need the second type (which will then need to produce simple maps or graphs); but operational staff doing on-ground work would probably go for the first type (and might require more technical info).'

'The focus of the questions has been surface water - groundwater requires more consideration.'

'There could be big risks in calibrating any model given the paucity of data and poor data collection methods.'

'Please make them idiot proof or not accessible to idiots.'

'The subjects covered in this survey seem to miss a couple of key points that would be easy to include and would increase the value of contaminant cycle models: (1) the role of dilution flows of relatively fresh water from some sub catchments blending with contaminated flows from others; (2) the importance of not reducing fresh water dilution flows through misguided tree planting; (3) the importance of care in the use of EC levels as these indicate not only NaCl salts; but other harmless salts.'

4 DISCUSSION

The compiled results from the survey provide useful information on the needs and preferences of the end-users of contaminant cycle models. The survey was successfully delivered to a wide range of model end users and the reasonable return rate suggests that there is much interest in the development of improved contaminant cycle models.

The delivery of survey questionnaire via an internet based tool may have biased the survey results to those with a greater technical understanding. However, this is not considered problematic given the context of the survey, i.e. examination of issues associated with the development of computer-based models. It is similarly difficult to assess the influence that use of existing models by survey respondents has had on the perceptions of end-users. The collective experiences of end users with existing models can potentially narrow the scope of responses. On the other hand, it enables objective responses to be given based on the strengths and weaknesses of existing models.

Several respondents commented that the types of contaminants that should be modelled are very often context and/or catchment specific. However, results from the survey suggest that a capacity to model sediment, nutrient and salt fluxes is a minimum requirement of future contaminant cycle models. The process representation necessary to simulate these contaminants provides a robust base for the simulation of a variety of other contaminants.

An ability to simulate landuse change, riparian zone management and point source control were the management practices that end-users considered most important for simulation in a contaminant cycle model. Consultants and researchers also ranked flow management highly – this was further supported by several comments from survey respondents. The influence of stream regulation and additionally water storages on contaminant source, fate and transport (dilution and concentration effects) is an important area of future research.

There is a diversity of potential impacts of contaminants on ecosystems and habitat value and this was reflected in the results from the survey. The development of generic qualitative (and where data exists to support it quantitative) methods for the assessment of ecosystem response is supported by the results of the survey. To achieve these outcomes there is a need for well focused fundamental research, particularly at larger spatial scales, to investigate the ecological response to changed contaminant loadings.

Results suggest that the preferred spatial extent for the application of contaminant cycle models is dependent on the type of user and often context and/or catchment specific (as already stated for considerations for contaminants). Models should have a flexible spatial structure that enables them to be modified to the spatial extent required for particular end-users. Models developed for application at spatial scales in the range of 10-100km² and potentially applicable at moderately larger spatial scales are suggested as a useful starting point.

End-users on the whole prefer historic climate records as inputs to contaminant cycle models. For model developers it is necessary that if other types of climate inputs, e.g. stochastic sequences, are to be used then the advantages that these types of inputs afford need to be well communicated to end-users.

Effective and simple communication to end-users is a key component to the success of the contaminant cycle modelling process. Simple methods are preferred by end-users for the representation of the results from these models. In particular, spatial analysis in the form of maps is much valued. As evidenced by the comments of several end-users, much value is placed in end-user consultation activities and such attempts should be encouraged as a vital part of the model development process. Similarly, there is a need to consider the role of modelling in decision making processes and potential for incorporation of model outputs into broader decision making frameworks e.g. risk based assessment and multi-criteria evaluation. End-users suggested increased integration of other modelled results and improved inputs into contaminant cycle models.

The survey lacked any questions concerning how to deal with the uncertainties associated with modelling. This omission was noted by several respondents. The majority of these respondents supported attempts to clearly and simply communicate model uncertainties to end users. Consideration of issues associated with uncertainty and attempts to make model outputs more transparent to all users are suggested as areas of future research.

5 CONCLUSION

The involvement of end-users in the contaminant cycle model development process is an important and necessary activity for the construction of effective models. Results from a comprehensive survey of a broad range of model end-users have been presented in this report. Several key conclusions can be drawn from the results:

- A capacity to model sediment, nutrient and salt fluxes is a minimum requirement of contaminant cycle models. The process representation necessary to simulate these contaminants provides a robust basis for the simulation of a variety of other contaminants which are very often context and/or catchment specific.
- A capacity to simulate the effects of common types of management interventions, importantly landuse change, riparian zone management, flow management and point source control, is a minimum requirement for inclusion in contaminant cycle models.
- A capacity to simulate the effects of contaminant loadings on ecological functioning and habitat values should be considered for inclusion as an integral part of contaminant cycle models. End-users ranked floodplain and riparian vegetation, macroinvertebrate population and algal biomass measures and indicators highly in that context.
- Contaminant cycle models need to be applicable across a relatively large range of spatial scales to meet the needs of a variety of end-user groups.
- The results from contaminant cycle models need to be effectively communicated to end-users. For effective communication, simple methods of representing the outputs of contaminant cycle models, for example maps, are preferred by the majority of end-users.
- Improvements are required in the estimation and representation of uncertainty in model outputs.

This report provides useful input to the development of contaminant cycle models that meet and exceed the requirements of end-users. Results from the survey will ensure that the development of such models will provide tools to enable end-users to explore the relationships between management activities and land and water conditions.

6 ACKNOWLEDGEMENTS

This research was undertaken as part of a project titled 'Development of a Catchment Contaminant Cycle Model for Stakeholder Use'. The project forms part of the National River Contaminants Program of Land & Water Australia and the Murray Darling Basin Commission. The authors are grateful to these agencies for their support. For more detail on the project see http://www.clw.csiro.au/research/catchment/contaminant_cycle/.

The authors are thankful for the comments on the content of the survey by a variety of technical specialists and model end-users. The authors appreciate the advice provided by Dr Brent Henderson (CSIRO Mathematical and Information Sciences) on the analysis of results from the survey.

7 APPENDIX 1: SURVEY QUESTIONNAIRE

The following is a list of the questions that were included in the survey. Where appropriate the options available to survey respondents are also listed.

- Q1. What activity are you mainly involved in?
Research; management; consulting; teaching; community representation; policy development
- Q2. What is your primary involvement with models?
I develop them; I evaluate/test them; I use them in my work; I commission their use
- Q3. What is your interest in management of contaminants?
Regional planning; river restoration; water quality improvement; fish restoration; landuse change
- Q4. Please rate the following contaminants according to your view of their importance for sustainable catchment management.
Total load; suspended load; bed load; turbidity; total nitrogen; NO_x (oxides of nitrogen); NH₄⁺ (ammonium); total phosphorus; filterable reactive phosphate; salt; pesticides; pathogens; water temperature; other
- Q5. Please rate the following management intervention options according to your view of their importance for inclusion in a catchment contaminant cycle model.
Landuse change; riparian zone management; gully stabilisation; river bank stabilisation; tillage practices; stocking management; groundwater pumping; point source control; water quality improvement devices; evaporation basins; flow management; other
- Q6. Please rate the following ecologic indicators according to your view of their importance of inclusion in a catchment contaminant cycle model.
Gross primary production; respiration; algal biomass; macroinvertebrate population; floodplain and riparian vegetation condition; water bird population; native fish population; other
- Q7. Please rate the following indicators of habitat value according to your view of their importance for inclusion in a catchment contaminant cycle model.
Substrate type (e.g. bedrock; sand; mud); pool/riffle sequences (depth variation); riparian shading; large woody debris; other
- Q8. Please rate the following catchment sizes according to your view of the spatial extent that a contaminant cycle model should be applied at.
0-1 km²; 1-10 km²; 10-100 km²; 100-1000 km²; 1000-10000 km²; 10000- 100000 km²; > 100000 km²

- Q9. Please rate the following time intervals according to your view of how a catchment contaminant cycle model should operate.
- Sub-daily; daily; monthly; annually*
- Q10. Please rate the following types of climate inputs according to your view of their importance as inputs to catchment contaminant cycle models.
- Representative (dry/average/wet) sequences; continuous historic sequences; synthetically generated (stochastic) sequences*
- Q11. Please rate the following measures of contaminants according to your view of their usefulness as outputs from catchment contaminant cycle models.
- Long term average annual load; annual total loads; annual average concentrations; monthly total loads; monthly average concentrations; daily loads; daily concentrations*
- Q12. Please rate the following spatial units according to your view of their importance for reporting results from a catchment contaminant cycle model.
- Catchment outlet only; sub catchment; hillslope; hillslope segment; stream reach*
- Q13. Please rate the following kinds of data visualization according to your view of their usefulness for stakeholders.
- Maps; time series; box plots; probability of exceedance graphs; animations; tabular (text) reports*
- Q14. What level of understanding do you think is required by each of the following stakeholder groups: technical specialists; regional/catchment managers; community groups?
- Minimal understanding of model required; understand how the model works in general terms; full understanding of the model; understanding of associated model sensitivity and uncertainty*
- Q15. Please include any general comments you have concerning the development and use of contaminant cycle models.