A Decision Support Tool for Prioritising Remediation Works in a Catchment/Estuarine Bay System

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Abstract: A Decision Support Tool (DST) has been developed to assist estuarine managers to determine catchment management measures likely to improve the water quality of Kogarah Bay, a tributary bay to the Georges River in southern Sydney, NSW. Using the DST, the fate of pollutants entering the bay can be mapped and time series plots of pollutant concentrations at particular locations can be produced for the duration of a modelled storm event. The initial concentrations of pollutants from six sub-catchment sources can be modified, allowing the input of up-to-date water quality data. Pollutant removal devices can be modelled within individual sub-catchments to determine the impact of potential remedial measures on pollution concentrations in the bay.

Keywords: *decision support tool, water quality, estuarine, hydrodynamic model, catchment management*

1. INTRODUCTION

Kogarah Bay, a tributary to the lower Georges River estuary in the Sydney region, has a highly urbanised catchment which impacts on the water quality of the Bay. Kogarah Council with the support of the NSW State Government's Estuary Management Program is preparing an estuary management plan for the area. The plan is to be based on a Process Study - which includes the development of decision support tools.

The decision to construct a DST to prioritise catchment treatments was driven by the need to clearly demonstrate cost-benefits of works as well as perform an educational function for councillors and community. It was also recognised that competition for remediation funding can sometimes lead to the situation where political pressures need to be balanced through emphasis on a process where science underpins the decision process.

Previous experience using a DST for water quality in a small estuary (Hinwood, et al., 2001) had shown that a simple but robust model could be utilised by an estuary manager without further specialist modelling expertise being employed. In this case (Kelso Creek, Bankstown, NSW) a very simple hydrodynamic model was adequate to predict pollutant transport and dilution. This model, with a water quality model was incorporated into a DST. This solution was not appropriate for Kogarah Bay due to the complex 2D hydrodynamics of the bay.

2. SETTING

Kogarah Bay is the most downstream embayment on the northern shoreline of the Georges River before it enters Botany Bay. Kogarah Bay is some 2.3 km in length and varies in width from 500 to 700 m and is relatively shallow. The foreshores have been extensively modified. The catchment is mostly urbanised with industrial, commercial and residential uses. Catchment drainage is mainly channelised with a large number of entry points to the bay (Figure 1).

Development pressures in the catchment have resulted in increased sedimentation in the bay with elevated levels of nutrients and metals in the sediments. Water-based recreational and ecological values have been affected by poor quality drainage from the catchment and influx of polluted water from the Georges River, as well as by sewage overflows in the local and Georges River catchments.

3. THE PROCESS STUDY

The Process Study objectives may be summarised as:

1. Undertake a study to determine the hydrodynamic processes operating in the bay under a set of critical flows from the sub-catchments and representative tide and wind conditions.

2. Estimate the flows and pollutant loadings from the sub-catchments under first flush and other selected flows.

3. Determine the source and fate of pollutants entering Kogarah Bay.

4. Develop a decision support tool to aid in determining the impact on the estuary of any future water quality remediation measures in the catchment.

Background information on the bay and catchments had been collated in the Issues and Values Study (Kogarah Council, 2001) and was supplemented by earlier studies of Kogarah Bay and the lower Georges River. This Process Study was commissioned by Kogarah Council with the support of the Estuary Management Program of the NSW Department of Land & Water Conservation and was conducted by Manly Hydraulics Laboratory, NSW Department of Public Works & Services (MHL, 2002). The Water Research Laboratory of the University of NSW conducted the numerical modelling.

Four catchment flows were selected to reflect the key pollutant delivery mechanisms to the estuary. The lowest discharge event, the First Flush, was selected according to recent research by Hogan (1999) where rainfall intensities above 7mm/hour were describe as producing a "cleaning event", promoting transport of sediment into the main drainage system; two higher flows (1:1 year and 1:10 year average recurrence interval) are capable of producing sewer overflow surcharging, and an intermediate event representing a more frequent rainfall event in the catchment.

Pollutants entering the bay are transported through the bay to the Georges River by net circulations and by dispersion processes. The principal circulation mechanisms are tidal exchange and residual currents, wind-induced circulation and cross-flow circulation induced by the tidal flow of the Georges River past the mouth of the bay. The principal processes causing dispersion are the tidal circulation and the wind. While dispersion is important it is likely to have a flushing timescale of a couple of weeks whereas the net circulations will have a timescale of about a week, depending on the location within the bay.

4. DECISION SUPPORT TOOL

The fourth objective of the Process Study was to develop a decision support tool, largely based on available information and data, to assist in determining what measures are likely to improve the water quality of the estuary. It was envisaged that the measures would include pollution control devices, and development control and planning measures to reduce pollutant loadings of tributary streams and drains. The measures are evaluated by running individual scenarios, specified by the user or previously stored in the database. The scenarios comprise a specification of the rainfall events, source concentrations and efficiencies of pollutant removal devices within each of the six sub-catchments. The DST has been designed to function as an adaptive management tool allowing redesign of scenarios as increased calibration data becomes available.

4.1 Structure of the DST

The structure of the DST can be viewed as comprising four functional components:

- expert input
- database
- user interface
- commercially available software platforms

The relationship between these components is illustrated in Figure 2 and the components are described in the following sections.

To install and run the DST, the user must have the software platforms MapInfo and MS ACCESS installed. The DST installation file is then executed which installs the DST and provides a starting icon. The DST can be accessed via MapInfo or directly, in which case the DST opens MapInfo.

4.2 Expert Input

The expert input to the database comprises output from a sequence of models covering the movement of water and pollutants through the catchment and into the bay, through the bay and out of the system into the Georges River. The major model components are summarised below.

4.2.1 The catchment model

Catchment modelling was undertaken using WBNM 2002 v100. It is an event-based hydrologic model and calculates flood hydrographs from storm rainfall hyetographs and can be used for modelling natural, part urban and fully urban catchments.

Runoff hydrographs were determined for four selected storm events for six sub-catchments making up the entire Kogarah Bay catchment. Pollutant concentrations for faecal coliform bacteria, total nitrogen, total phosphorus and suspended solids were determined for each of the six sub-catchments.

4.2.2 Hydrodynamic model

A hydrodynamic model of Kogarah Bay and the surrounding waterways was established using the two dimensional finite difference model RMA 2. The model was used to compute velocity and water level data for the four storm events.

4.2.3 Water quality model

Input to RMA 11 used the pollutant loads from each of the catchments and the velocities from RMA 2, to determine pollutant concentrations throughout Kogarah Bay. In addition to the pollutants listed in 4.2.1, the dilution of a conservative pollutant released from each of the six sub-catchments was evaluated.

4.2.4 On-going monitoring

An on-going water quality monitoring program is proposed and the data are to be passed to the database via the user to generate updated scenarios reflecting the measured source and pollutant removal efficiencies.

5. DATABASE

5.1 Resource data

This database component is constructed from the modelling outputs as previously described and comprises MS ACCESS files containing the following information:

- computational nodes - identifier and coordinates
- rainfall events - identifier (<1 year, 1 in 1 year, 1in 10 year, first flush)
- water quality concentrations - each of the listed pollutants as functions of time from start of the event, node, rainfall event, source number
- pollutant decay rates

5.2 Dynamic data and scenarios

This is the interactive and updatable database component where specifications of pollutant removal devices are stored. These can be added to or specifications changed manually. Additionally, the discharge scenarios which drive the operational component of the DST are stored within the database structure allowing them to be reused and modified at the discretion of the user.

6. SOFTWARE PLATFORMS

An important aspect of the design of the DST specified by Kogarah Council was the use of familiar software platforms in order to reduce staff training and facilitate exchange of DST output with other council programs and applications.

All database information is stored in MS ACCESS format and interrogated through specially designed SQL queries. The structure and queries have been developed to facilitate incorporation into MapInfo GIS.

The MapInfo GIS system provides the graphical user interface (GUI) that, in conjunction with the MS Access database, provides a visual display of the interactive scenario results. It allows the users to spatially and temporally visualise specified model results. MapInfo interfaces with the MS Access database via an ODBC connection using SQL, MapBasic and Visual Basic code. It uses standard interpolation techniques to create contours of pollutant concentrations in Kogarah Bay.

7. USER INTERFACE

MapInfo provides the front-end for the DST, with a link to the ACCESS database and options for producing contour plots of pollutant concentration in the bay as well as time-series plots at user-specified locations.

There are three SQL queries used in the database. The user selects or specifies a rainfall event, set of discharge concentrations and pollutant removal devices prior to running each query.

- The Contour Data Query calculates the total concentration at each node in the Kogarah Bay area at a specified time.

- The Time Series Query calculates the total concentration at a particular node for each time step.
- The Average Contour Query calculates the average concentration from all time steps at each node and then produces an average concentration contour plot.

A drop-down menu is provided in MapInfo to access the following DST functions:

- Select and edit scenarios
- Create time series plot
- Create contour plot
- Create contour plot (next time step)
- Create contour plot (average)

These functions invoke custom MS ACCESS forms as described below.

7.1 Select and edit scenarios

The MS ACCESS database form for selecting and editing a scenario is shown in Figure 3. The functions are selected via buttons at the top of the screen. The parameters which can be specified by the user to build a scenario include:

- Constituent concentrations of nitrogen, phosphorus, suspended solids, faecal coliforms, optional additional constituents
- Locations of pollutant removal devices
- Efficiency of pollutant removal devices

A scenario number and name are selected to enable subsequent retrieval of the scenario which is stored in the dynamic section of the database. A drop-down menu for each sub-catchment/source allows the user to select which type of pollutant removal device is to be used. The efficiency characteristics of each device can be checked or changed by use of the *Edit Pollutant Removal Devices* button.

7.2 Graphics output

The final four functions which may be selected from the drop-down menu in MapInfo specify the graphics option to be used in presenting the output of the DST.

The three contour plot functions produce a map of the bay, with the cadastral layer and source locations shown. The map displays coloured contour bands of pollutant concentrations in the bay. When using any of these functions, the MapInfo *Zoom, Grabber* and *Info* tools can be used to manipulate the display and to find out the pollutant concentration at previously specified nodes. An example of a contour plot is shown in Figure 4.

To compare the results of two or more scenarios on the screen (e.g. pre and post pollutant removal devices) it is necessary to save the *Concentrations Layer* produced for the first scenario before creating the second using the MapIfo *Save Copy As* function.

The *Create Contour Plot (Next Time Step)* function allows the user to move to the next time step in the previously selected scenario.

When using the *Create Contour Plot (Average)* function the user must specify a scenario and a pollutant. A contour plot is produced showing the average concentration of that pollutant over the 504 hour duration of the modelled event.

The *Create Time Series Plot* function allows the user to select a particular node within the bay and produce a time series plot showing the concentration of a specified pollutant throughout the duration of the event (see Figure 4). As in Figure 4, it is possible to view this plot in the same window as a contour plot on which the selected node location may be shown.

As well as the standard screen plots included in the DST, MapInfo allows a range of output plot formats and styles, facilitating information transfer to other local government and community reporting formats.

8. DISCUSSION and CONCLUSIONS

The use of expert knowledge in estuary management is conventionally undertaken via the employment of scientific and engineering consultants and usually necessitates repeated commissioning of such staff or organisations as increased knowledge and familiarity with the particular estuary generates the need for increased data resolution and/or better process understanding. Thus adaptive management of the estuary is made more unwieldy and costly through having to employ such experts relatively frequently.

The approach outlined in this paper illustrates a mechanism whereby different management scenarios may be explored by trained council staff without such frequent and costly reference to experts. It should be made clear, however, that, if major changes in understanding or techniques arise, the initial work underpinning such a DST will need to be revised. Within the bounds of current knowledge and data availability for Kogarah Bay, the present DST will provide significant efficiencies and cost savings to the operation of the estuary managers. Similarly, the ability to compare cost-benefits of proposed pollutant removal strategies in each of the sub-catchments for Kogarah Bay will provide optimum environmental and economic outcomes in a transparent and accountable fashion.

The DST uses catchment and hydrodynamic model results, database storage and analysis and graphics functions to allow the user to select catchment management devices/strategies and specify pollutant interception efficiencies within any sub-catchment and model the pollutant fate over a set range of catchment flows. A visual interface in the database enables the DST user to input specific parameters and design scenarios, which are then processed in the database. The use of such a DST permits interactive modelling of complex scenarios and the selection of cost-effective catchment treatments without further costs associated with specialist modelling advice. A further benefit is the ability to use the DST as an educational tool. The DST has taken its place as an on-going operational tool within the local government structure.

9. REFERENCES

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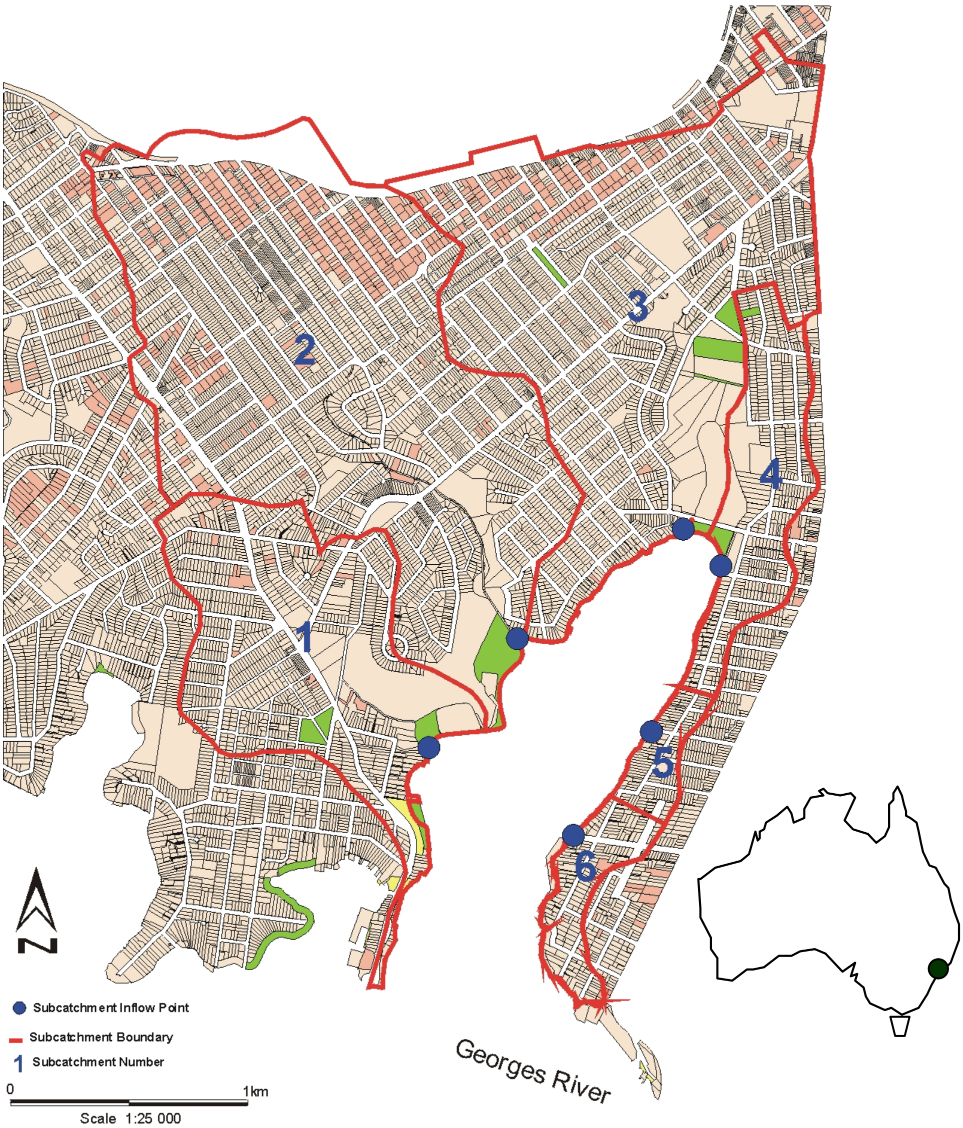

Figure 1. Kogarah Bay and sub catchments.

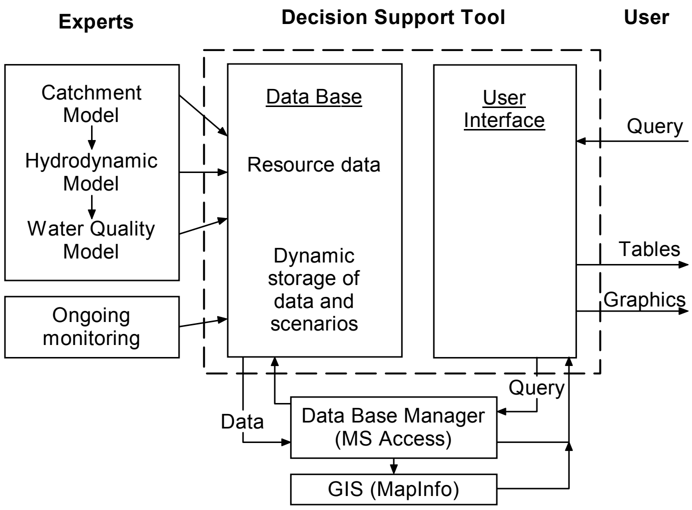

Figure 2. Structure of Decision Support Tool

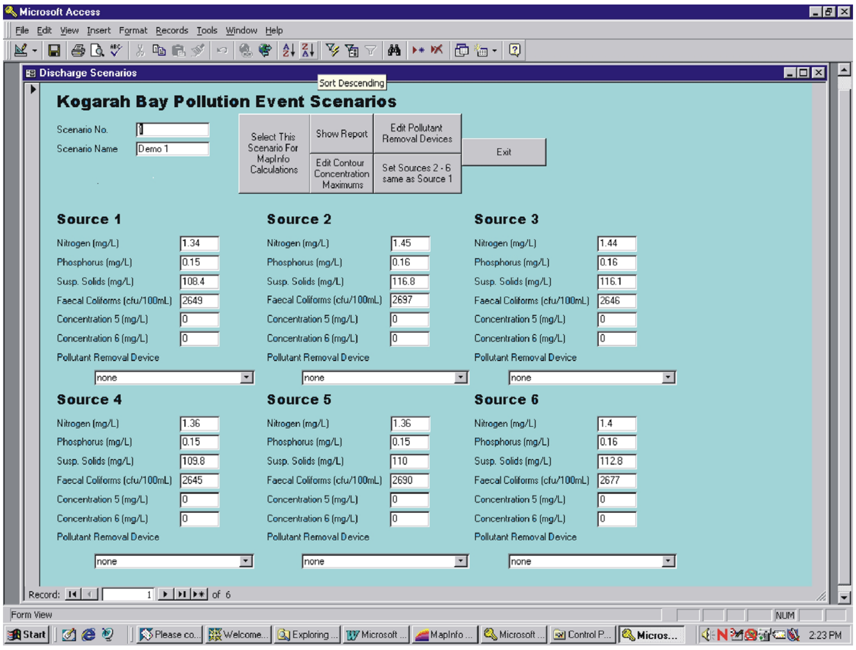

Figure 3. Database input screen used to create scenarios and edit parameters

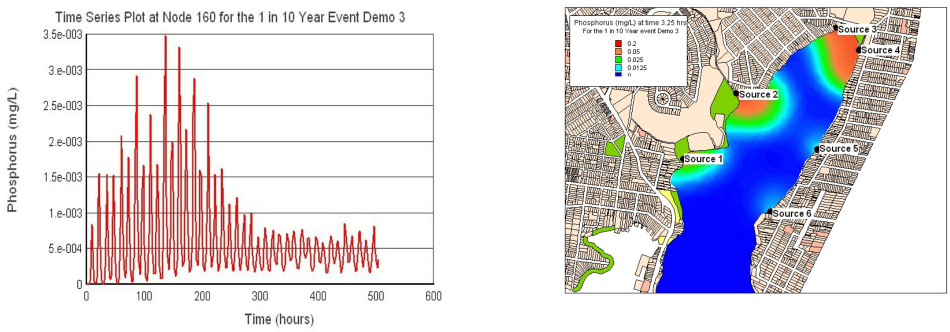

Figure 4. Example of output: time series plot at a node and contour plot of concentrations.